SITE: FL Phosphate Initiative
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An Overview of

Mining Operations

And

Reclamation Techniques

in the

Severance of Phosphate in Florida

8/99 Draft prepared by Florida Phosphate Council from earlier Bureau of Mine Reclamation Draft

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A HISTORY OF PHOSPHATE MINING IN FLORIDA

While phosphate was predicted to occur in Florida as early as 1868, phosphate was first found in Florida by accident during an investigation of building stone in a quarry at Hawthorne, Alachua County, in 1880. In 1883, Dr. C. A. Simmons began mining this rock and converting it into fertilizer. However, the project was abandoned the next year for lack of capital.

In 1881, Captain J. Francis LeBaron discovered phosphate along the banks of the Peace River in Central Florida and mining began in 1888. Phosphate was first mined from the bottom, edges, and sandbars of the river. Hand methods prevailed at the first river pebble mining operations with lumps of rock loaded upon barges for transport to the washer. Primitive steam dredges rapidly replaced hand loading. Dredges were located on floating barges and the dredged materials were transferred to washer barges to separate phosphate pebble from foreign materials, sand, and clay. The rejected material was returned to the river. The phosphate was then transported by scow down the river to the phosphate works for drying and a final screening.

By 1908, river production of phosphate pebble was completely replaced with on-shore production. Overburden, the non-phosphate containing material lying above the phosphate ore, was removed by pick and shovel, horse-drawn scraper, steam shovel, or hydraulic methods. The phosphate rock was removed initially by picks and shovels with the larger companies upgrading to steam shovels. When land pebble mining replaced hard rock mining, the pebble was excavated using hydraulic jets. Unlike river production, land mining left visible pits and depressions. Many of these areas were backfilled with the fine-grained phosphate and sand particles rejected by the screening process. In other cases this rejected material was stockpiled in large mounds. Today, these mound areas are being re-mined to recover the fine particle phosphate.

Hydraulic methods were introduced about 1902 along with electricity to replace steam power. By 1904, pick and shovel mining ended. The era of hydraulic mining occurred between 1908 and 1920 and disturbed approximately 5,700 acres. The majority of these disturbed acres have since reclaimed themselves naturally and are no longer easily identified as mined acres.

New advancements in the extraction of resources occurred in the 1920's that greatly accelerated the mining of phosphate in the state. In 1920, draglines were introduced to remove overburden. While the first dragline was diesel powered, electric-driven, self-propelled draglines soon became the standard. By 1929, electric draglines were universally used to remove overburden for land pebble mining. Draglines were also used to remove hard rock phosphate when the ore was deeper than could be reached by dredges. Overburden for this deeper phosphate continued to be removed hydraulically until the demise of hard rock mining in 1965. Electrically driven draglines

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greatly increased the digging capacity and allowed the mining of deeper deposits. The use of this new technology resulted in a different landform after mining. Parallel rows of overburden were separated by longitudinal pits that were larger and deeper than those created by hydraulic mining.

A second innovative technique that revolutionized the industry and increased both the quality and quantity of phosphate was the development of a flotation process. The flotation process, first introduced in 1928, recovers the fine phosphate particles that were previously discarded as waste and doubled the amount of phosphate recovered in pebble mining.

As phosphate was mined to deeper depths, clay particles became a larger percentage of the phosphate ore. This clay became a major concern for the industry with regard to its handling and disposal. An easy method was to dispose of the clays in the pits created from the mining of the phosphate matrix. However, the clays do not easily settle from the water used to separate the clays and sand from the phosphate. The large volumes of water and clay quickly exceeded the storage capacities of the pits. This disposal method is referred to as below-grade storage of clays. In order to have sufficient capacity to store clays, the industry developed above-grade storage. Above-grade storage places the water and clay in an earthen dam impoundment. This allowed more clay to be stored on the same amount of area. Over time, the clay settles to the bottom and clear water remains on top. Above-grade storage allows this clear water to be drained from the system, increasing the total amount of clay that can be stored. These clay storage impoundments are referred to as clay settling areas.

When laws that regulated the reclamation of disturbed phosphate lands became effective in 1975, over 149,000 acres of land had been disturbed. Of these lands, 143,000 acres or 96 percent were disturbed after 1920. The majority of these lands were mined by draglines and resulted in lands consisting of parallel rows of overburden, longitudinal pits, and clay settling areas.

The rate at which these disturbed lands were created increased as mining and the separation of phosphate from the clay and sand became more efficient, and the demand for phosphate rock increased. Approximately half of the acreage disturbed between 1888 and 1975 occurred in the fifteen-year period between 1960 and 1975. This amount of disturbance in such a relatively short time span increased the visibility of mining operations and generated public concern over past and future disturbances. On July 1, 1975, the reclamation of future disturbed phosphate lands became mandatory through state law.

Since 1975, the methodology and techniques used in mining operations have changed little. The rate of mining has remained relatively constant with fluctuations as a result of the economy and product demand. However, major advancements in water conservation and in the reclamation of these disturbed lands have occurred. The major

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portion of this manual will discuss the development of these advancements and the innovations created by the industry and others in meeting the provisions of state laws.

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GEOLOGIC FORMATION OF PHOSPHATE

The depositional environment of phosphatic sediments in Central Florida is very complex. Theories attempting to explain the origins of the deposits include chemical precipitation, carbonate replacement, reworking of deposits, fecal droppings, particle growth, and biochemical processes. Some experts believe in a single source while others favor a combination of these theories. The unique geologic characteristics of Central Florida's Bone Valley Formation is complex enough to support many of the theories.

What is known, however, is that the Florida phosphate deposits are sedimentary deposits of marine phosphorite origin. These sediments were laid down during Miocene time when Florida was covered by shallow seas. As sea levels rose and fell, conditions were very favorable for the precipitation of carbonate fluorapatite. During these numerous episodes of sea level changes, the sediments were worked and reworked resulting in size differentiation, pelletizing, and concentrating of the sediments that had been originally laid down. A time table showing the depositional history of Central Florida during this time is shown in Figure 1. A drawing of the paleogeography describing the middle Miocene for this same area is shown in Figure 2.

The deep, cold sea water from the north, containing about 0.3 parts per million phosphate, met shallow, warm water covering Florida and containing about 0.01 parts per million phosphate. The solubility of phosphate in water decreases as temperature and pH increase. This change in temperature and water chemistry caused the phosphate particles to precipitate out. The constantly changing seas during this time deposited a layer of phosphatic clays, sands, and gravel along the coastal shelf.

The phosphate was a nutrient for the tiny plants that in turn supplied most of the nutrients for the marine food chain. With plenty of food, marine life flourished, lived, and died, and was deposited along with the sediments. As the polar ice caps formed during the late Miocene, the ocean receded from the Florida peninsula and the land was again exposed. The land was very fertile due to the phosphate and marine animal remains. The area was a subtropical savannah inhabited by many terrestrial animals. However, the ever changing climate and sea levels forced the animals south where they eventually died. Subsequent sea level changes eventually worked the fossil remains into the sediments to join the phosphate and marine fossils.

In Central Florida, described as the mining district within the Bone Valley Formation, the sea deposited its dissolved phosphate in a low, shallow embayment located in what is today southwest Polk and eastern Hillsborough Counties. The deposition was controlled by the Ocala High to the north, the Hillsborough High and Valrico Ridge to the west, the Winter Haven Ridge and Lake Henry Ridge to the east, and ultimately a deep open sea to the south. Figure 3 shows a paleogeographic drawing of the local

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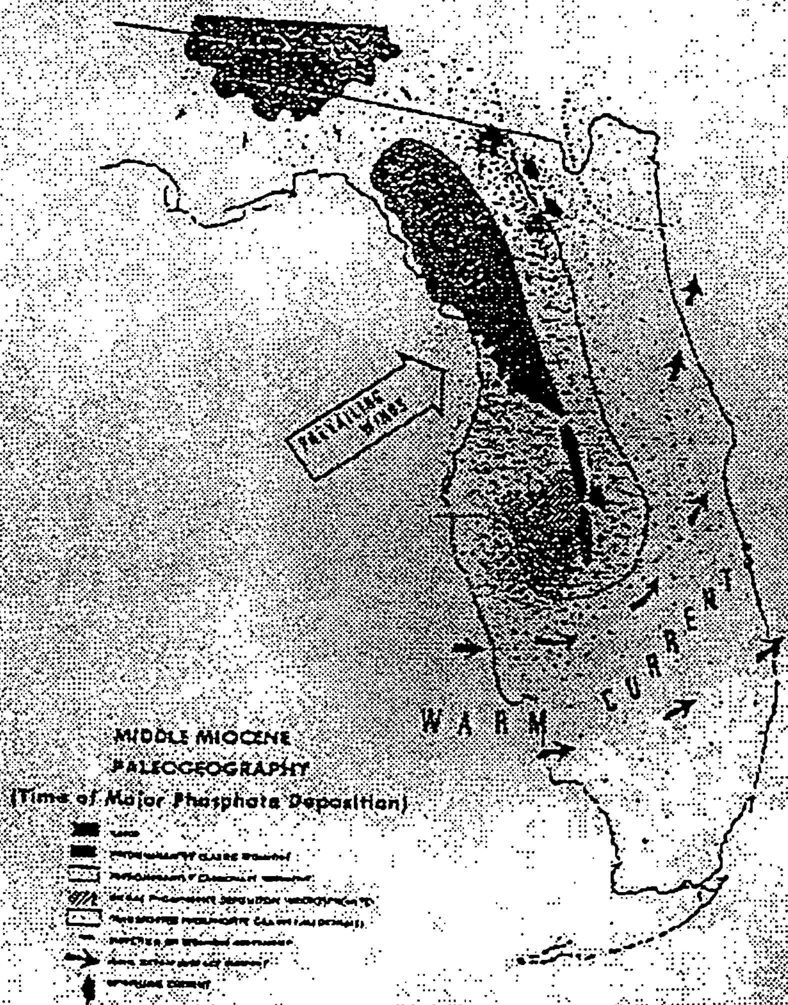
Generalized Stratigraphy of Central and South Florida

Geologic Period		Age MM Years	Sedimentary Strata	Thickness	Ancient Environment
Holocene & Pleistocene		0 - 2.5	Surficial Sands	10'	Variable - Mixed Land & Marine
Pliocene		2.5 - 7	Leached Sands & Sandy Clays	15'	Variable - Mixed Land & Marine
Miocene	Upper	7 - 12	Bone Valley Formation (Largely Mineable)	150'	More Marine than Land
	Middle	12 - 18	Hawthorn Formation (Partially Mineable	150'	Mostly Marine Minor Land
	Lower	18 - 26	Tampa Formation (Trace Phosphorite)	150'	Greatly Marine Trace Land
Oligocene		26 - 28	Suwannee Limestone	125'	Marine
Eocene	Upper	38 - 42	Ocala Group Limestone	200'	Marine - Possible Late Exposure



Middle Miocene paleogeography, showing phosphorite deposition, direction of sediment movement, main ocean surface current, and upwelling current. Source: Freas and Riggs (1968).

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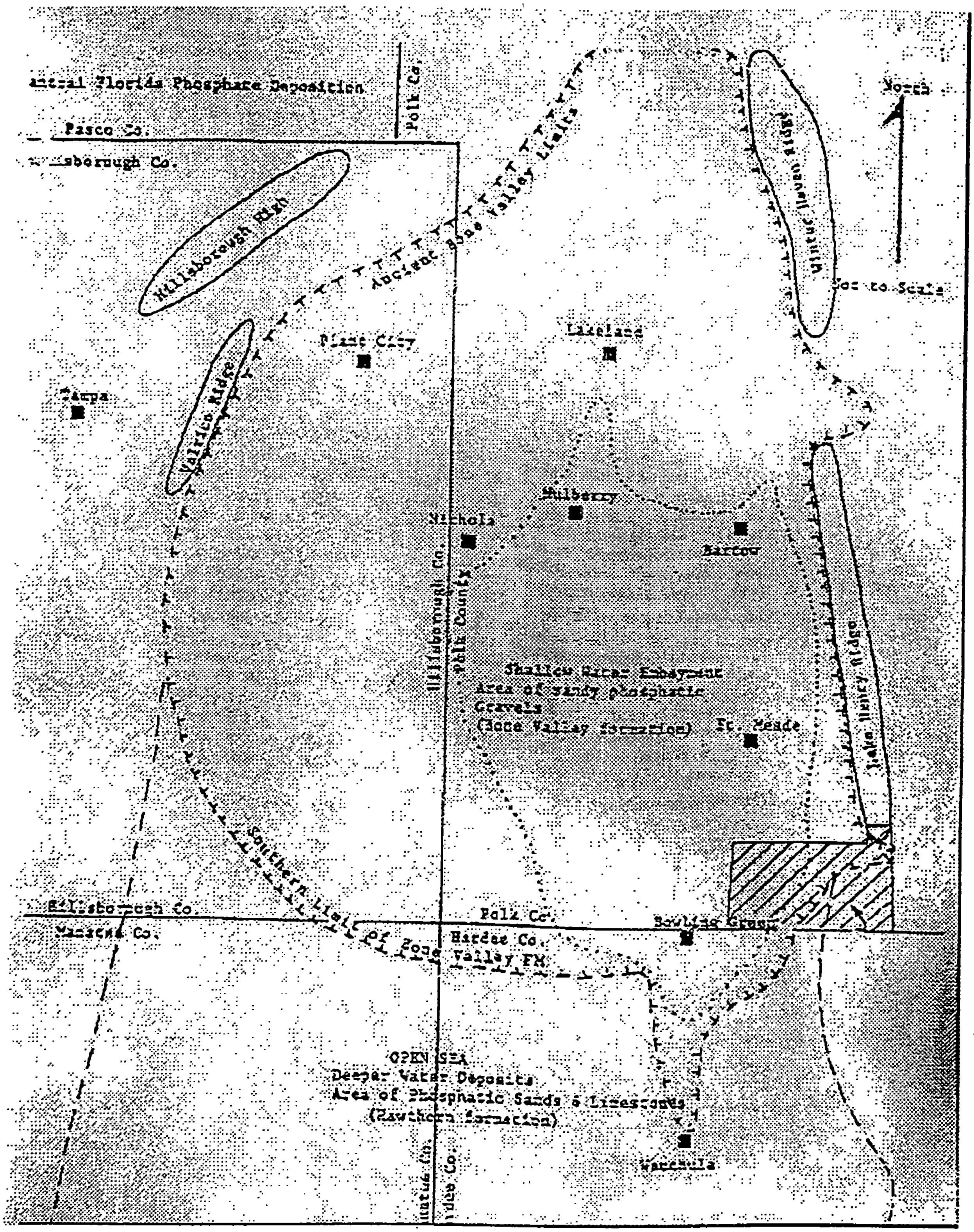
Florida Phosphate Deposition
Pasco Co.
Polk Co.
Hillsborough High
Ancient Bone Valley Limits
Winter Haven Ridge
North
Not to Scale
Lakeland
Plant City
Tampa
Valrico Ridge
Mulberry
Nichols
Bartow
Hillsborough Co.
Polk County
Lake Henry Ridge
Shallow River Embayment
Area of sandy phosphatic
Gravels
(Bone Valley formation)
Ft. Meade
Southern Limit of Bone Valley FM
Hillsborough Co.
Manatee Co.
Polk Co.
Hardee Co.
Bowling Green
OPEN SEA
Deeper Water Deposits
Area of Phosphatic Sands & Limestones
(Hawthorn Formation)
Hardee Co.
Wauchula

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area. The economically mineable portion of the Bone Valley Formation is a matrix of sand, clay, and phosphate. The deposit varies in thickness from five feet to twenty-five feet. The deposit is overlain by strata of sand and clay, referred to as overburden, that must be removed prior to mining. The overburden typically varies in thickness from five to fifty feet. Figure 4 shows a typical cross section.

The Bone Valley Formation contains one of the richest reserves of fossils in the United States. More than seventy extinct species of marine and terrestrial animals have been found, including; camels, horses, mastodons, rhinoceroses, giant ground sloths, bears, saber-toothed cats, crocodiles, whales, and turtles. Rare finds include; a twenty-five foot long Baleen whale that was the first intact whale skeleton found in the southeast, the skull of a six-horned antelope was also the first found in either North or South America, the only *Nannippus minor* or three-toed horse skull ever found, and the first intact skeleton reported east of the Mississippi of *Rhinoceros teleoceras.*

Phosphate makes up about one-tenth of one percent of the earth's crust. Economically mineable deposits of phosphate are found in only a few places in the world. The unique and complex geologic and chemical conditions that existed in Central Florida ten to twenty million years ago resulted in one of the richest formations of phosphate in the world.

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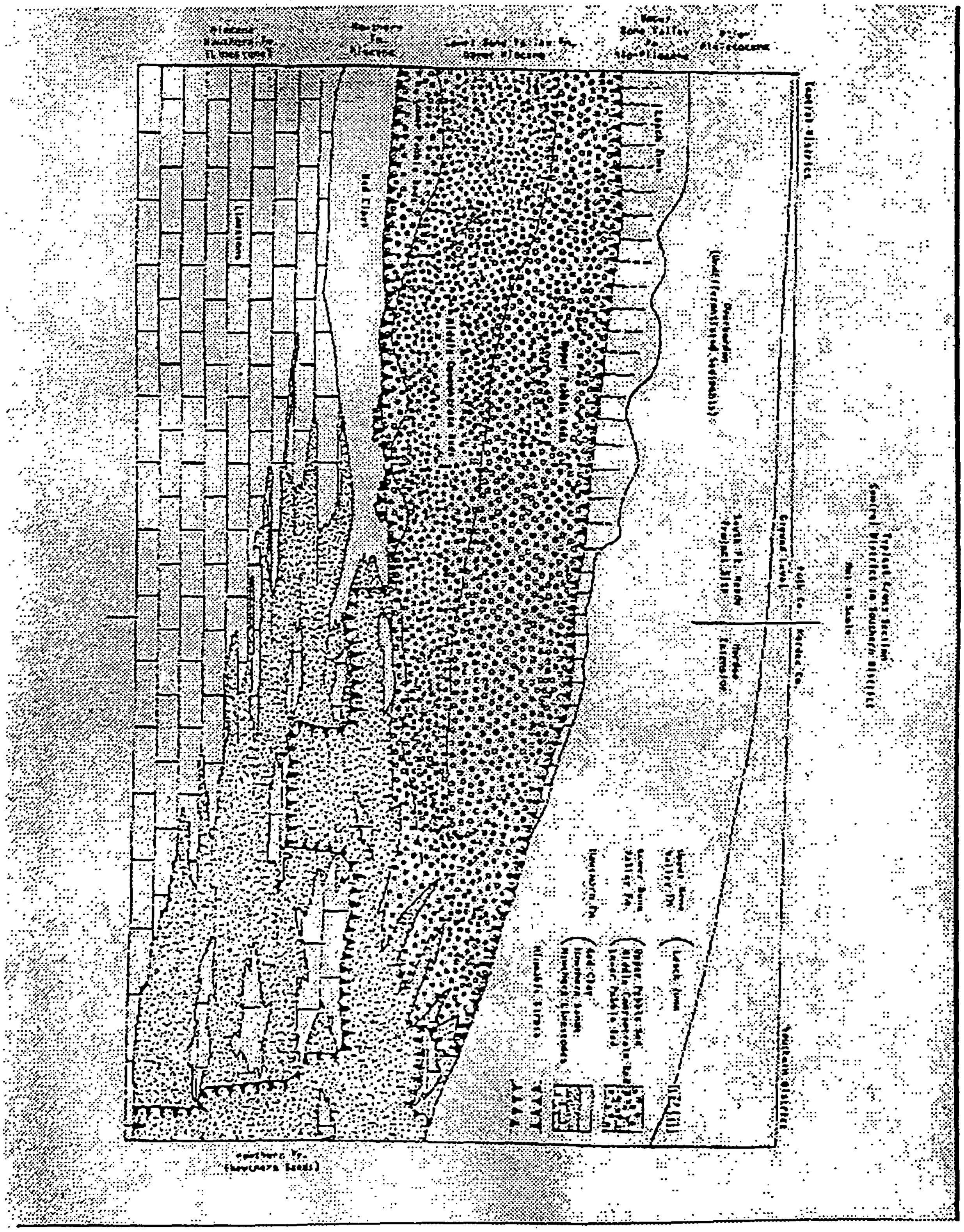
Typical Cross Section
Central District to Southern District
Not to Scale
Central District
Polk Co.
Hardee Co.
Southern District
Ground Level
Overburden
(Undifferentiated Sediments)
South Ft. Meade
Project Site
Hardee
Extension
Leach Zone
Upper Pebble Beds
Middle Conglomerate Beds
Lower Pebble Beds
Red Clay
Limestone
Leach Zone
Upper Pebble Bed
Middle Conglomerate Bed
Lower Pebble Bed
Red Clay
Hawthorn Sands
Hawthorn Limestones
Hawthorn Fm.

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PHOSPHATE MINING OPERATIONS IN FLORIDA

Introduction

Florida is the third largest, non-fuel mineral producing state in the nation. The largest percentage of Florida's mineral production comes from phosphate mining. Florida supplies over 75 percent of the nation's demand for phosphate and currently produces more than 25 percent of the world's phosphate supply. The phosphate industry creates thousands of jobs. For every job created directly by the industry, statistics have proven that approximately 5 jobs are created in support industries. The mining industry also creates a unique and important tax base by paying a severance tax for each ton of phosphate mineral removed from the ground.

Mining operations conducted in Florida are technically and logistically complex. Thousands of acres of land must be acquired and permitted. Expensive beneficiation plants are required and state of the art infrastructure for handling rock products and mining by-products such as clay and sand tailings must be planned and constructed. Due to the nature of the mining and beneficiation processes, large tracts of land are temporarily disturbed and large quantities of water are used on a daily basis. By proper management of the resources, the disturbed land is rapidly returned to productive use through land reclamation and approximately 97 percent of the water used each day is recycled. Cooperation with federal, state, and local regulatory agencies is also helping to minimize impacts through proper planning and communication.

This section on mining operations is a general overview of the basic mining processes. Each company will have variations on the processes, although the general processes are essentially the same throughout the industry. The reclamation process will be mentioned in this section, but is covered in depth in another section of this document.

Active Mining

Once the site is acquired, permitted, and the infrastructure is in place, mining operations begin with proper site preparation. All marketable timber and other resources of economic value are removed and sold. Remaining vegetation and unusable structures are cleared and removed. The ground is leveled to make a stable base for operation of the dragline and ancillary mining equipment. Mining cuts are laid out by survey crews. The cuts vary in width and length depending on the size of the dragline, depth of mining, and configuration of the mining site. Adjacent undisturbed habitats are protected by installation of berms and perimeter ditches. Additional planning for and installation of protective measures along streams, rivers, lakes, and

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wetlands are completed prior to the initiation of mining. A typical mine cut sequence is depicted on the accompanying Mine Cut Sequence Drawing #1.

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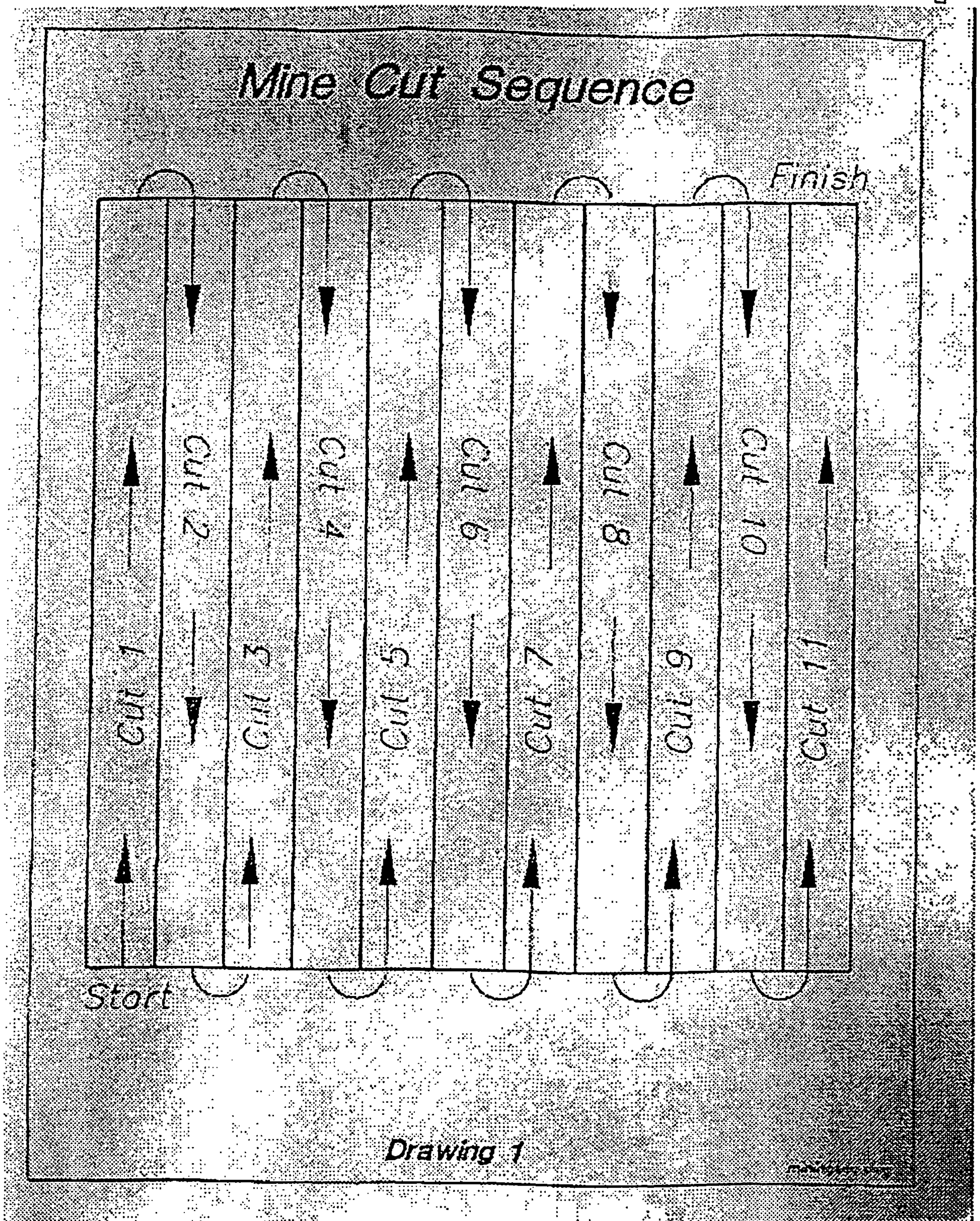

Drawing 1

The areal extent of land clearing and site preparation prior to mining is minimized. By limiting the amount of exposed soils, the potential soil erosion by wind and rain, and the potential for producing dust are reduced. This practice also keeps wildlife habitat and

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productive pastureland in place for longer periods and reduces the period of time that land is out of productive use.

After site preparation and the installation of the mining infrastructure are complete, excavation of phosphate ore is initiated. The geology associated with phosphate deposits is discussed in detail in another section of this document, however a few basic geologic and mining terms must be reviewed to understand the mining process. In general, the phosphate ore zone is covered by an overburden layer that can vary in thickness from 0 to >100 feet, although the overburden layer is generally less than 80 feet in thickness. The overburden consists primarily of sand and clay without significant phosphate minerals. The ore zone is a "matrix" consisting roughly of one-third quartz sand, one-third clay, and one-third phosphate minerals of various sizes. These percentages will vary greatly from site to site and matrix strata to matrix strata, but are a rough approximation of average distribution. The terms, phosphate ore and phosphate matrix, are used interchangeably within the mining industry. A drawing of a typical geologic cross section used in planning purposes is attached as Drawing #2.

Recovery of the phosphate matrix proceeds in the following sequence:

The overburden covering the matrix zone is stripped off and cast into the previous mine cut where it becomes part of the fill material for reclamation purposes. When a sufficient area of matrix is exposed, mining of the matrix zone is initiated. Matrix is excavated by dragline and cast into an earthen sump, commonly referred to as a well. Once placed in the well, the matrix is turned into a liquefied slurry by gunning the matrix with high pressure water from remotely controlled water guns. These guns produce a high pressure stream of water from a 1 to 3 inch opening at approximately 200 psi. Once slurried, a pit pump with a suction pipe approximately 20 inches in diameter, picks up the slurried matrix and begins the pumping process to the beneficiation plant where the phosphate minerals are separated from the clay and quartz sand components of the matrix. The water guns, pit pump, and suction are controlled from a small mobile control room called a pit car. The well, pit car, and pumping equipment are commonly referred to collectively as the Rock Pit. Drawing #3 shows a typical plan view of a mining site.

The excavation process continues until the matrix is removed down to hard, unprocessable bed clay or rock formations across the entire leading edge of the mine cut. At this time, the dragline is moved away from the leading edge of cut, and steps backward a sufficient distance (approximately 100 feet) to begin the overburden removal process again. Cross sectional and plan views of the mining sequence are attached as Drawing #s 1 and 4.

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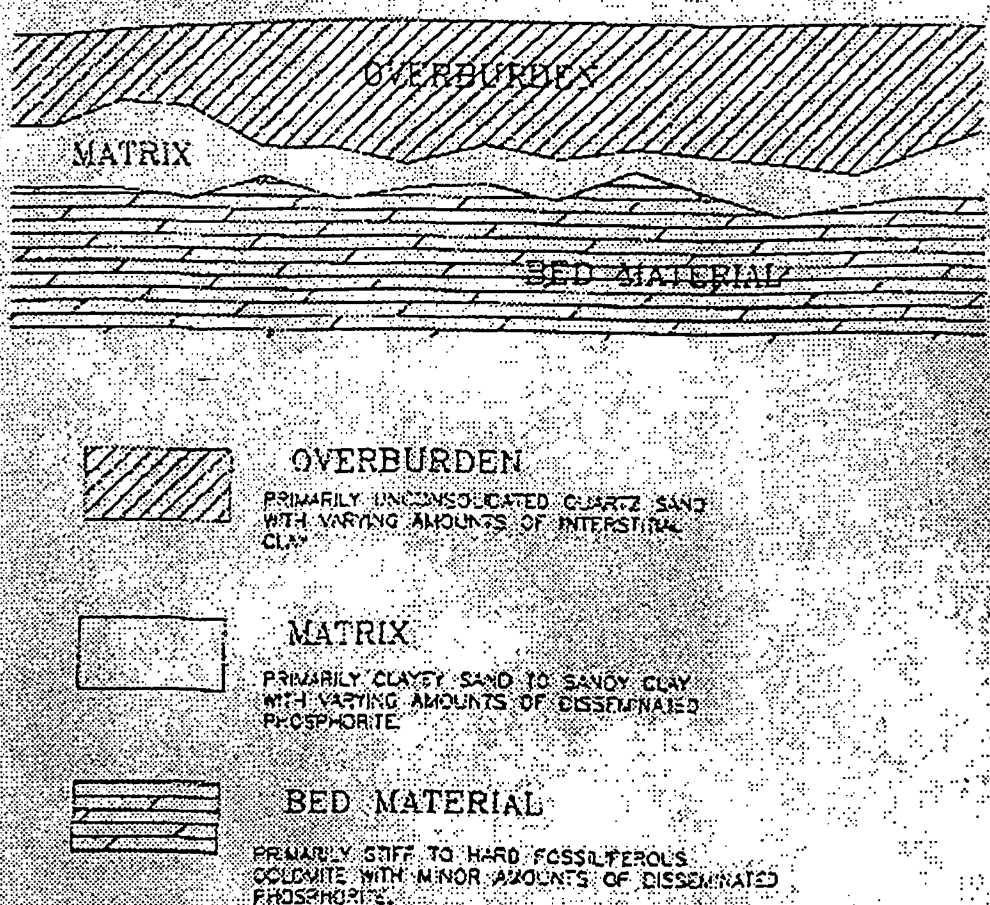
Typical Geologic Cross Section



Drawing 2

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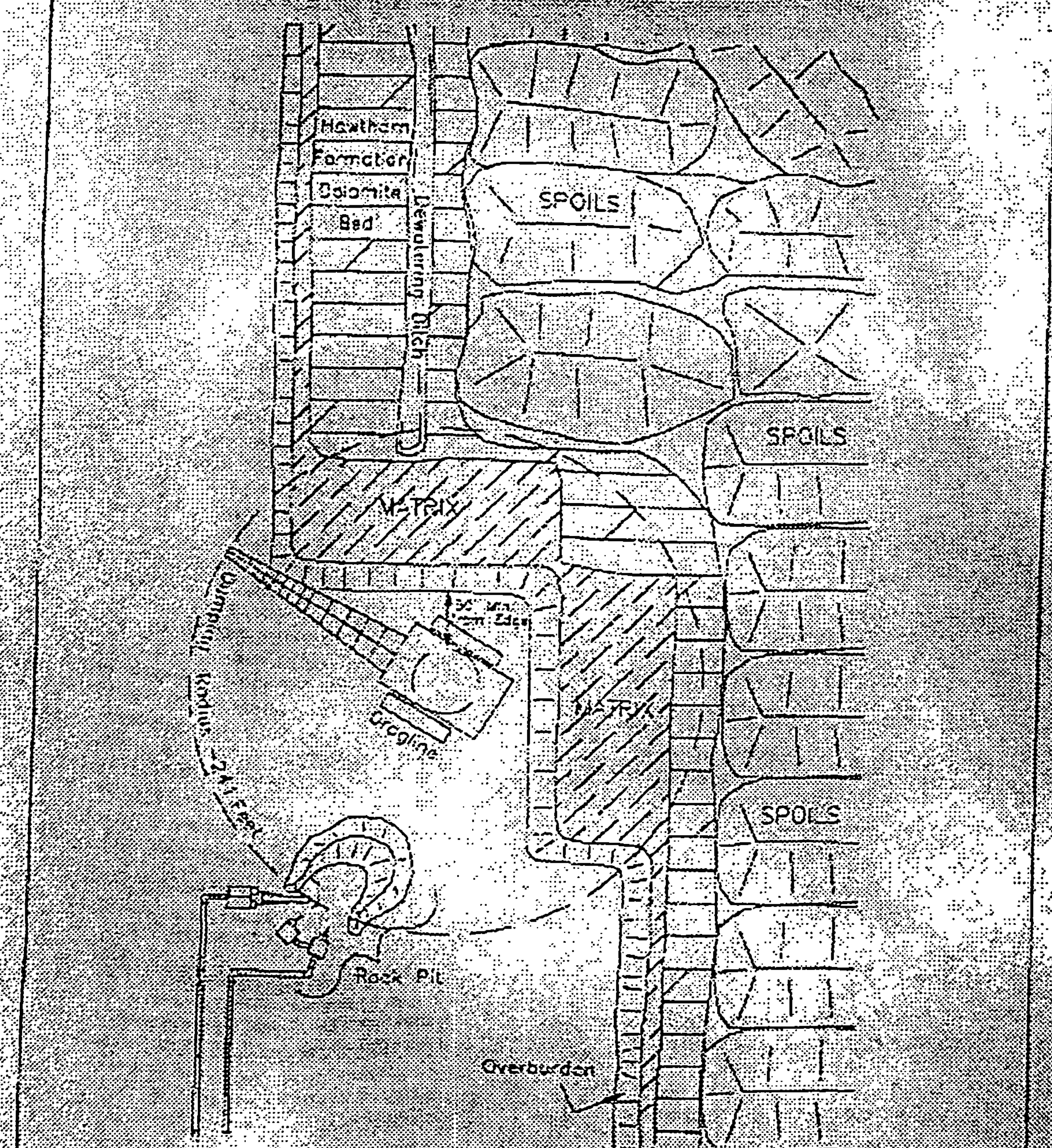
Typical Plan View - Mining Site



Drawing 3

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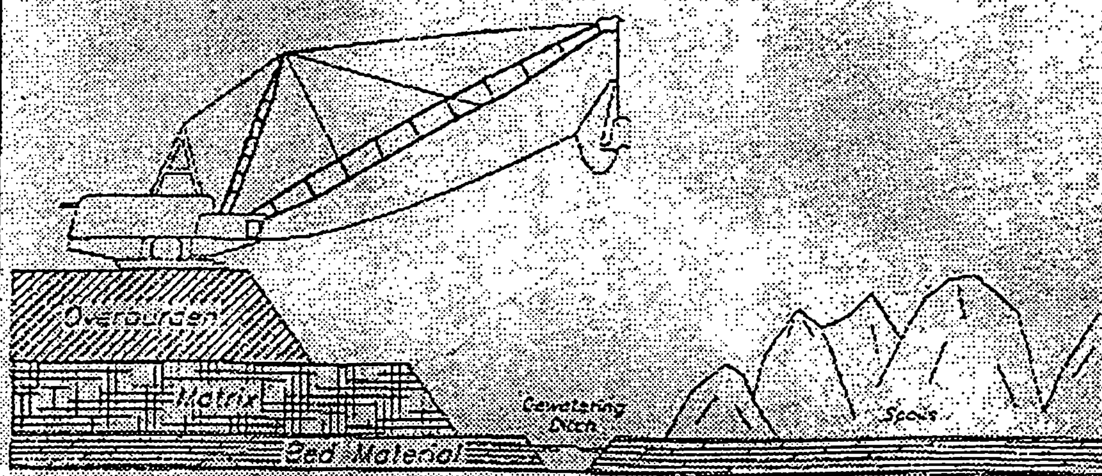
Typical Cross Section - Mining Site



Drawing 4

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Overburden Management

Overburden placement and management is a critical aspect of the mining sequence. As overburden is removed it must be placed in areas that will not interfere with matrix excavation, or mine cut water removal. It also must be stacked so that a minimal amount of dragline movement is required to remove all the overburden. Overburden spoil piles are often unstable after they are first stacked and care is taken not to place the spoils where they can slump and damage mining equipment or cause injury. Flexibility to place overburden to benefit future reclamation is impractical due to reach limitations on the draglines. Reclamation designs must take into account the final placement of overburden in a site in order to maximize restoration efficiency and designs are sometimes "field adjusted" to account for overburden placement. The first cut in any new mining site poses unique problems with overburden placement. The initial cut is called a "box cut" since it is enclosed on all four sides. Overburden from the box cut must initially be placed above grade adjacent to the cut and then as much as possible in the cut as mining progresses. This creates stability problems with the cut embankments and mine cut water removal. Advanced planning and pre-mining site dewatering can help eliminate problems encountered with box cuts.

Matrix Separation (Beneficiation)

After the matrix is slurried at the rock pit and picked up by the pit pump, it is pumped through steel pipelines that are generally 18 to 24 inches in diameter, to the mine beneficiation plant. The pumping system uses large booster pumps spaced at strategic intervals in the matrix pipeline in order to keep the matrix slurry moving through the pipeline. The beneficiation plant's primary purpose is to separate phosphate minerals from the sand and clay matrix through mechanical screening and flotation units. The general sequence for matrix separation and product recovery in a beneficiation plant is as follows.

As the matrix slurry arrives at the beneficiation plant from the mine site, it flows over stationary screens that remove oversize materials such as clay balls or large carbonate rocks that could degrade the final product. In many beneficiation plant designs, oversized materials are discarded into old mine cuts or placed in clay settling areas. This oversize material is usually larger than one inch in diameter. The next set of screens are smaller mesh size screens that are either vibrating or stationary and are angled to enhance the movement of the pebble from the upstream to the downstream end of the screen. Phosphate pebble remains on top of the screens and continues to move onto additional screens and clay scrubbing devices until a clean pebble product arrives at the end of the circuit and is transferred to either a storage bin or a stockpile for shipping. Sand and clay size particles fall through the screens and are collected for further separation. Clay is separated from the sand size particles (sand tailings and phosphate) by a series of hydrocyclones. The hydrocyclones separate the phosphate

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and sand from the clay mixture using centrifugal forces. By spinning the mixture, the lighter materials (clays) are separated from the heavier materials (sand tailings and phosphate) with the clays leaving the top of the hydrocyclone and the sand tailings and phosphate being discharged at the bottom.

The sand collected contains a significant amount of sand size phosphate minerals mixed in with quartz sand. Typical beneficiation will separate a coarse fraction from finer grains by mechanical screening with fine screens. This mixture of sand and phosphate is then sent through a two step flotation process. Chemical reagents in flotation cells selectively attach to the phosphate mineral or quartz sand depending on the stage of the process. Air injected in the bottom of the flotation cells creates air bubbles that float the attached phosphate or sand particle, depending on the process. The "froth" is then skimmed from the top of the flotation cell. The concentrated phosphate or concentrate is then pumped to bins for storage or to stockpiles until it is shipped to chemical plants. The remaining quartz sand is commonly called tailings sand and is returned to the mine site as fill material for land reclamation. Small amounts of the sand are also used in clay settling area dam construction as a pervious material for toe drains.

The beneficiation process produces sand and colloidal clay as by-products. These by-products were historically considered to be useless wastes. In modern mining operations, sand tailings serve an important function as reclamation fill. Colloidal clays produced as a by-product are routed to large earthen impoundments called clay settling areas. The clay settles from the water column and clarified water is returned through spillways to the beneficiation plant as process water for mining and beneficiation operations. As the clay settling areas reach the end of their useful life, they are commonly reclaimed as productive farm lands or habitat areas.

Mining Water Use

Phosphate mining operations require large volumes of water for the mining and beneficiation processes. Extensive water recirculation systems are constructed within the mining operations in order to maximize water return from sand tailings and clay settling areas to supply water to the plant. Modern mining operations typically recycle approximately 97 percent of the water used on a daily basis. The remaining 3 percent is lost through seepage, evaporation, transpiration, product removal and shipment, and clay retention.

Water losses are made up from mine cut water, rainfall catchment, and deep well pumping from the Floridan Aquifer. Although the volume of water withdrawn on a daily basis is substantial, the phosphate industry is a leader in developing water systems that maximize water recycling and minimize withdrawals. Some of the methods used include: water cropping during high rainfall periods, filtration systems for circuits requiring relatively pure water so that recirculating surface water is used rather than

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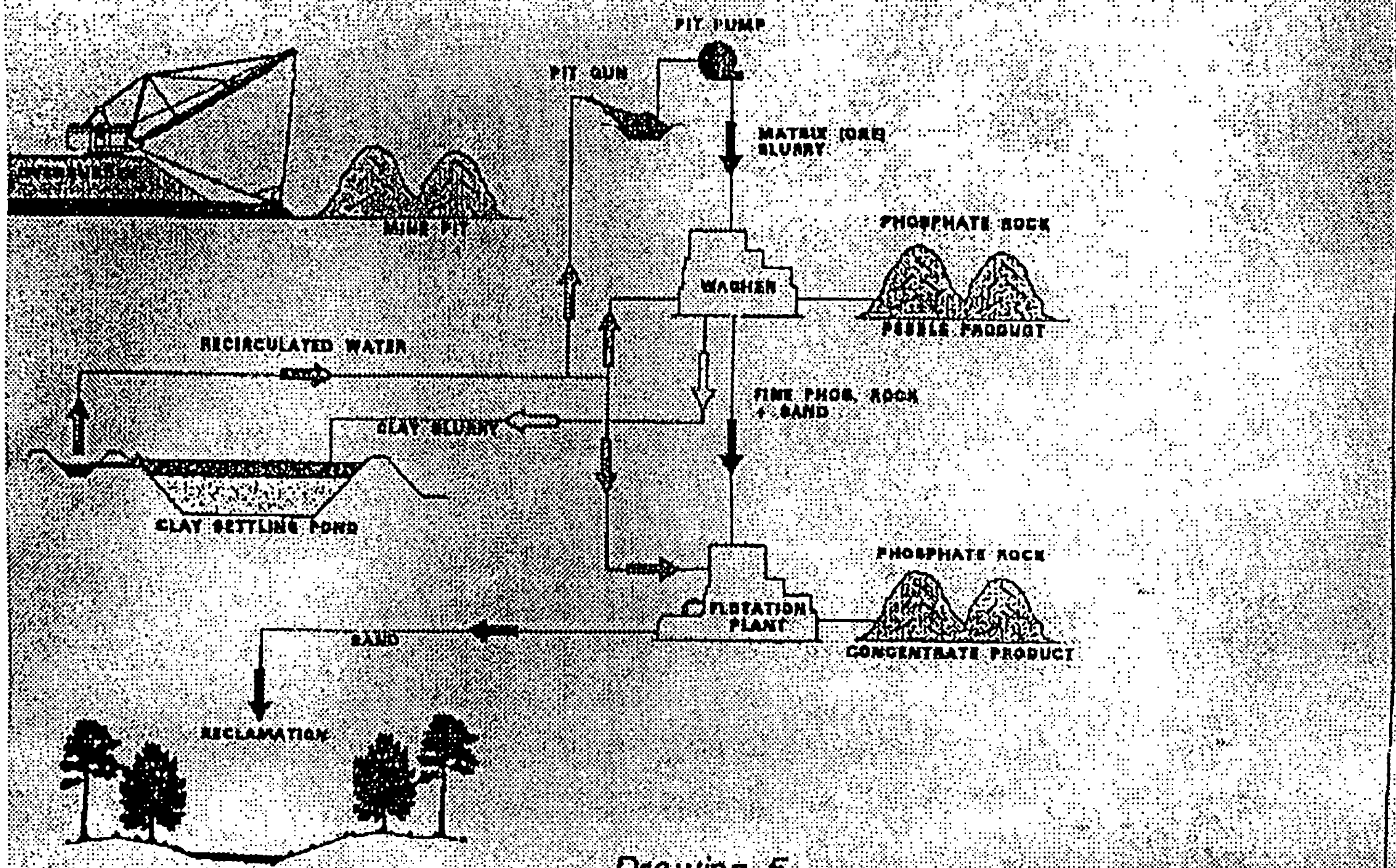
well water, use of recirculating surface water to seal booster pumps, and increased efficiency in pumping systems. By using water conservation methods and improving efficiency in water systems, mining operations have been able to reduce deep well pumping by 85 percent over typical volumes pumped in 1970.

The various systems such as the clay settling areas (clay settling pond), water recirculation ditches, mine cuts, and beneficiation plant (washer and flotation plant) location are indicated in a generalized way on Drawing #5.

Phosphate Mining Operations



Drawing 5

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RECLAMATION – EARTHMOVING COMPONENT

INTRODUCTION

Phosphate mining can create large-scale disturbances to Florida lands and watersheds where the reserves are mined. Vegetation is cleared; 20 to 70 feet of the surface geology is excavated; wetlands and water bodies may be drained; historic land-use patterns may be interrupted; and drainage patterns are interrupted or re-routed. However, through reclamation, these disturbances are rendered temporary, and impacts to the environment are minimized.

If reclamation did not occur on these lands, vegetation would independently colonize the disturbed area. However, the land would not necessarily function properly in terms of its ecology, drainage patterns, or land use. Reclamation practices in Florida are planned to replace ecological and hydrological functions and restore the economic potential of mined land.

Mandatory state reclamation laws have evolved since their inception in 1975 to provide for certain functional requirements. Some of these provisions include: acre-for-acre and type-for-type replacement of wetlands, at least ten percent reforestation of uplands, forested "greenbelts" in and around water features, the re-establishment of pre-mining drainage patterns, and attainment of State water-quality standards. State funds have also been made available for reclamation of lands disturbed by mining but not subject to mandatory reclamation requirement ("non-mandatory" lands).

State reclamation laws also provide for development of mine-wide conceptual plans that address the appropriate locations of clay settling areas, sand tailings disposal sites, land-and-lakes reclamation, and other mining operations features. Typically, conceptual plans take into account creation of different landforms and balance residual clay, sand, and overburden to create topographies that would mimic the pre-disturbance watersheds. Additionally, conceptual plans address reclamation land use patterns and land cover characteristics and how they complement each other and surrounding areas.

Reclamation in Central Florida has progressed beyond the mine-wide conceptual plans and now takes regional features and land use patterns into consideration. The Bureau of Mine Reclamation has developed a concept that considers the entire Central Florida phosphate district. This concept is known as an Integrated Habitat Network (IHN), discussed later in detail. Through the IHN, the industry is encouraged to establish greenways or wildlife corridors on a regional scale, sometimes restoring corridors that were fragmented by activities unrelated to mining. These greenways provide support for certain animal species that require large habitat areas, enhance water quality in

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streams, and establish recreational opportunities in the form of trails and camp sites.

Through land and monetary donations, wetland mitigation, and the Nonmandatory Land Reclamation Trust Fund, the State has implemented a program to restore six major watersheds in the Central Florida phosphate district. The intent of this reclamation is to replace culturally disrupted watersheds with those that are functionally restored.

The following information discusses, in general, the reclamation of phosphate disturbed lands. This information is not intended to be comprehensive. Rather, it is an overview of the types of reclamation techniques and methodologies used by the industry in meeting state reclamation requirements.

DISPOSAL, DEWATERING, CONSOLIDATION, AND RECLAMATION OF CLAY SETTLING AREAS

Introduction:

The phosphate ore ("matrix") excavated from the mine cuts contains roughly equal amounts of sand, clay, and phosphate rock. The sand and clay are separated from the phosphate rock in a process called beneficiation. Residual clays are placed in clay settling areas. A typical clay settling area is approximately one square mile in area. These clays, along with overburden, sand tailings, and other materials such as soil and muck, are used to re-establish the topography and provide a fertile growing medium for vegetation.

One of the major challenges in early phosphate reclamation was to reduce the amount of time necessary for reclamation of clay settling areas. Before reclamation was mandated on disturbed phosphate lands, it was often decades before these clay settling areas consolidated sufficiently to support reclamation. Today, with improved technology and practices, it generally takes only a few years to reclaim the clay settling areas once they are removed from service. Thus, these lands are being reclaimed and are providing environmental and economic benefits to the region in a fraction of the time it once took.

This section will take a look at the issues, concerns, challenges, innovations, science, and reclamation of clay settling areas.

Physical Elements of a Clay Settling Area:

Prior to regulation of clay settling areas, most dams were constructed from loosely-cast overburden (the material that is excavated to expose the matrix). Engineering standards were generally not applied to these dams. Overburden was simply piled and roughly shaped to form embankment walls. Some of these systems failed, causing acute damage to rivers and streams. Today, dams are rigorously engineered and

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designed to meet safety and environmental requirements imposed by the state and local governments.

Generally, modern clay settling areas are approximately one square mile in size, and embankments may extend vertically 20 to 40 feet (or more) above natural grade. Most of these clay settling areas are located on mined land, and dam embankments are constructed from overburden or sand tailings. The exterior and interior slopes are designed to maintain the integrity of the dam and are often 3H:1V. The bottom elevation of these areas is typically 40 feet below natural grade. When overburden is used for dam wall construction, it is taken from the interior of the area, thus creating more volume for the clay and reducing the areal extent required for clay settling.

A slurry of clay and water is introduced into one end of the typically rectangular impoundment. The clays settle slowly, and clear water is decanted over an adjustable overflow riser type spillway. The distance between the inlet and spillway provides adequate time for clays to settle out.

The slurry from the beneficiation plant contains around three percent clays (solids by weight). As these clays settle, they reach a density of approximately 12 percent solids within 90 days in the clay settling area, although some types of clay take longer to reach this density. The discharge at the spillway removes relatively clear water that is recirculated back to the mining and beneficiation operations.

Operating criteria for dams require that the maximum surface water elevation never exceed a height greater than five vertical feet below the dam crest. This five foot safety factor is referred to as the "freeboard" and ensures that overtopping of a dam is highly unlikely.

Clay Settling Area Dewatering and Clay Consolidation

Removal of the water column from above the settled clays, known as dewatering, serves to expose the clay surface to the effects of sun and wind and accelerate clay consolidation. The percent solids of the clays taken as an average over the entire clay settling area is typically about 25 percent after dewatering. This is about the consistency of toothpaste.

Once the surface water is off the clays, efforts are expended to expedite clay consolidation in order to increase the stability of the area sufficiently to safely support the personnel and equipment necessary for reclamation. The consolidation of the clay results from reduction of the water trapped between the clay particles.

In understanding how consolidation of clays occurs, it is important to know how the water entrapped between the clay particles is removed. The clays effectively seal the sides and bottom of a clay settling area, limiting lateral or downward movement of

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water. Therefore, the only significant way for water to be removed is through the top surface.

Experience has determined that the most effective way to dry the surface clays is to expose them directly to the effects of the sun and wind. As the water is removed from the clays, the clay particles are bound closer together, thereby, greatly reducing the total volume of the material. This change in volume results in cracks formed in the clay surface. This act of volume reduction and the resulting formation of cracks are called "desiccation." Desiccation is one element in the overall process of consolidation.

Further desiccation is accomplished through disking of the surface clays to expose more clay surface area to the evaporative effects of sun and wind. As desiccation results in a thicker, more dense layer of surface clays, the effective weight on the softer underlying clays is increased, forcing the water from the softer clays upward and increasing the overall consolidation of the clays. The process of desiccation of the surface clays is commonly referred to as "crustal development."

Early Attempts of Clay Consolidation:

In the early 1980's, the industry was required by the Governor and Cabinet to develop innovative techniques to consolidate "clay settling areas," as a condition to their conceptual plan approval. The industry was challenged with finding a method that: Would meet "state reclamation standards," could be applied to mass quantities of clays, was not detrimental to the "environment," and resulted in a reasonable cost. The following are some of the methods tried:

Flocculation – This method uses a chemical to make the suspended clay particles in the water attract to themselves, making them heavier and settle faster. The clay settling of the particles was successful; however, it did not enhance ultimate consolidation. This, coupled with the expense of available flocculents, rendered this option as unpractical. However, it continues to be an area of interest.

Cofferdams – A clay settling area was divided by interior dams into four (or more) segments. Clays in one segment would be dewatered and allowed to consolidate, while another segment received clays. The intent was that the clays in one cell would consolidate before receiving additional clays. Thus, the clay settling areas would ultimately hold more clays. This method was determined to be impractical.

Centrifugal Force – A machine was developed that spun the clays rapidly and forced water out. The clays formed small balls or pellets. Capacity limitations, high costs and the practicality of clay transport limited the viability of this method.

Quiescence – In this method, clay settling areas were dewatered and allowed to be inactive (rest) for several months to a few years. This resting period provided time

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for a crust to develop and reduced the volume of clays in the clay settling area before they were put back into service to receive additional clays. The amount of time necessary for consolidation to occur often took the ponds out of service for too long, resulting in clay production that exceeded the available storage. Over the life of a mine, this method, used in a stage fill sequence, can reduce clay settling acreage.

Dragged Torpedo Ditcher – A device was developed that would float on top of the clays and would cut a ditch (like a plow) by being winched across the clay surface. Difficulties with this method were quickly determined. It was nearly impossible to stretch the drag cables across the clay settling area and over dense vegetation. The device was unstable as it was dragged, having a tendency to flip over and veer off course. It was also impeded by the large willows and other vegetation growing on the clay surface.

Dynamite – Charges of dynamite were placed in a series aligned where a ditch was desired. The dynamite was exploded in a time sequence with the intent of creating a ditch. The shock from the explosion caused the clays to fluidize and flow back in place.

Perimeter Ditch Method:

One of the early methods tried proved to be feasible and practical and became the standard method of operation for many years. This is the "perimeter ditch method." Once the clay settling area had been dewatered and a crust started to develop, a ditch was cut along the interface of the dam and the clay surface. The ditch depth was limited by the fluidity of clays. Therefore, the ditches were constructed in steps as adjacent clays consolidated and became less fluid. Construction of the perimeter ditch began at the spillway riser and extended in both directions approximately one-third to one-half of the distance around the clay settling area.

In combination with the perimeter ditches, amphibious tractors, commonly referred to as Gemco's (the name brand), are used to develop interior ditches. These amphibious tractors have large balloon-like tires, very low ground pressure, and can generally traverse across consolidated clays for a short distance before needing to be pulled out. As they travel they develop a depression in the clays using a hydraulic ditcher that serves to drain water from the interior to the perimeter ditch.

Over time, the perimeter ditch is deepened and as the clays continue to consolidate, the process is continued. With each subsequent pass, the amphibious tractors can extend the interior ditches farther out into the clay settling area, reducing the remaining pool of water and deepening the interior ditches.

Although this method of consolidation was the best approach for many years, it has some drawbacks. Considerable time is required for the repetitive ditching process. As

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the clays consolidate, a reverse grade on the interior ditches commonly occurs. As the center of the clay settling area consolidates it becomes difficult to establish a perimeter ditch bottom lower than the lowest point on the consolidating clay surface. Accordingly, some areas are now consolidated using a center ditch instead of a perimeter ditch. From this center ditch, interior ditches similar to those used in the perimeter ditch method are constructed.

There are several advantages of using the center ditch method. The time required to consolidate the clay settling area is about half that of the perimeter ditch method. Additionally, more complete consolidation is achievable because it is easier to establish a positive grade to a center ditch. While the initial costs (per linear foot) for establishing the center ditch are higher, the amount of ditching required is significantly less, resulting in better consolidation at a lower overall cost.

Dam Abandonment and Breaching of the Dam:

When clays in a clay settling area have consolidated and become stable, the dam is no longer needed to contain them. The mine operator will then request that the clay settling area be "abandoned." This activity requires a permit and is conducted under the supervision and approval of an engineer registered in the State of Florida. The engineer will conduct all tests and investigations necessary to certify that the embankment can be removed with no environmental or safety consequences. Upon certification and agency approval, the dam is breached and considered abandoned.

The breach is generally a cut through the embankment made near the spillway (outlet) end of the clay settling area. Dam abandonment is necessary before other reclamation activities can occur.

Reclamation of a Clay Settling Area:

The clay inlet pipe is typically located on the highest elevation of the natural grade of the clay settling area and the outlet spillways are located on the natural grade low side. This establishes a gradient in the same direction as the pre-mining drainage pattern.

Reclamation of a clay settling area occurs after it is abandoned and when adequate crustal development has been obtained to support reclamation activities. The clays are generally between 30 and 40 percent solids when reclamation begins. The majority of the necessary earthwork is to reduce the slopes and height of the embankment. State reclamation standards require all slopes be 4H:1V or less steep. Cutting the materials at the top of the dam and placing it as fill at the dam's toe, usually using bulldozers, achieves the required slope and height objectives. Operators generally reclaim embankment walls by sloping them as flat as possible and pushing some of the embankment material out over the consolidated clays. The visual effects of a clay

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settling area, especially when the dam is long and straight, are not totally eliminated by the reclamation earthmoving process.

The reclamation of a clay settling area includes the removal of the spillway riser and discharge pipe. Because the riser was serving as the drainage structure for the surface of the clay settling area, other methods to convey water from the elevated clay surface to the drainage outlet are generally needed. To properly manage and control these waters, the mandatory reclamation program allows a detention pond that slowly drains down a rip-rap swale. These detention ponds are commonly vegetated with wetland species to help with the issues of water quantity and quality.

Once a sufficient crust has been developed, the clay surface is disked in preparation for revegetation.

Clay Consolidation Modeling:

Computer modeling of clay consolidation is used to predict the amount of time to achieve consolidation, surface elevations, and percent solids that can be expected when certain factors or conditions are applied. These models can predict these parameters for any time during the consolidation process. It is important to know that the models do not yield an absolute answer. Rather, they provide estimates on the dimensions and number of clay settling areas that will be required at each mine. Modeling also provides an assessment of the degree of change in the final reclaimed configuration that can be expected as other factors are manipulated.

Sand-Clay Mix Reclamation:

In response to the challenge by the State and some local governments to develop innovative technologies to consolidate and reclaim clay settling areas, some companies have developed a sand-clay mix process. Sand-clay mix refers to a process in which sand and clay components, separated during mining and beneficiation, are recombined into a suitable mix for disposal in a mined area.

The sand, when mixed with the clay, results in a soil that has a higher permeability than the clay alone. This higher permeability translates to an increased rate of dewatering of the clays over conventional clay settling.

In the mix process, the clays generated from the beneficiation plant are routed to a containment area, referred to as the initial clay settling area, for storage and subsequent consolidation to a higher percent solids. When clay consolidation reaches the 12 to 18 percent range, the clays are removed by dredge and pumped to a mix tank for mixing with dewatered sand tailings from the beneficiation plant. The sand-clay mixture is then pumped from the mix tank to a designated disposal site. Disposal areas are designed to receive sand-clay mix over mined lands to final fill elevations that

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consolidate to within approximately 2-3 feet above the original average pre-mining elevation by the end of reclamation.

Crustal development similar to that described previously for clay settling areas is also employed to enhance the time required for final reclamation of sand-clay mix areas.

SAND TAILINGS FILL AND RECLAMATION:

As with the clays, sands are separated from the phosphate rock during the beneficiation process. This sand, commonly referred to as "sand tailings," is ideally suited to fill the voids left from removal of the phosphate matrix. Reclaimed contours similar to those existing prior to mining are usually achieved. However, due to the high cost of pumping, prior to reclamation laws, it was a common practice to dispose of sand tailings in large piles.

Sand tailings are much easier to dispose of than clays. Sands do not require consolidation or artificial dewatering. In fact, they can be graded almost immediately upon placement. Sand tailings are generally deposited between the overburden rows of mined-out areas.

Sand tailings slurry is pumped from the beneficiation plant through mine pipes to the disposal area. The water from the slurry clarifies very quickly and generally is pumped or drained by gravity into the mine water recirculation system where the majority of it is reused.

The discharge pipe is monitored by mine operators and the pipe is continuously relocated and directed so that the proper placement of the sands can be achieved. The proper placement of these sands can greatly reduce the amount of required grading necessary to achieve the reclaimed topography.

The overall reclamation mass balance for any given area takes into consideration not only the sand volume but also the volume of overburden remaining in the mine cuts. Once the sand tailings have been placed and graded, the overburden peaks are often graded over the sand tailings, creating a cap.

Overburden is typically a loamy-sand or sandy-loam, with greater moisture holding capacity and fertility than sand tailings. Overburden is suitable for a variety of vegetative assemblages.

In some cases, sand tailings are left un-capped to create unique habitats that add to the diversity of the reclaimed sites, including the creation of xeric communities. These xeric communities support populations of scrub jays and gopher tortoises.

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LAND AND LAKES RECLAMATION:

The conceptual reclamation plans developed for each mine address the overall material mass balance. One of the goals of the conceptual plan is, to the greatest extent practical, the redistribution of material to maximize the amount of land reclaimed to its approximate original grade. However, because of the way mining byproducts need to be managed, transported, and stored, voids are left in some mining areas without material available to fill them. These voids are typically reclaimed as lakes.

Most lakes are reclaimed near the end of the mine life. The beneficiation plants are located near the geographic center of a mine to reduce material transport distances to and from the mine site. Disposal sites (sand tailings and clays) are located as close to the plant as practical to reduce pumping costs, enhance the ease of maintenance, and to increase the efficiency of the water recirculation system. Therefore, some of the more remote areas of the mines will not receive fill from the beneficiation plant and will be reclaimed as "land and lakes."

Typically, spoil from the lake interior is removed and used to create as much upland area around the lake as possible. Some spoil is occasionally left in the lake interior to create islands for birds. Wetlands or littoral zones are contoured and vegetated within the lake perimeter and they must cover at least 25% of the total lake area. Slopes are contoured to 4H:1V or flatter. The contoured void is allowed to fill with natural groundwater, rainfall, and storm water runoff. Because the lake bottom is typically a residual phosphate deposit, these lakes are usually eutrophic (fertile). This fertility, coupled with a varied depth regime fosters the development of productive fisheries in reclaimed lakes.

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RECLAMATION - REVEGETATION AND VEGETATIVE COMMUNITY DEVELOPMENT

INTRODUCTION

Once mining of the phosphate has occurred, the reclamation process begins. The first step is the contouring. The level of effort and time for contouring depends on the type of reclamation, either sand tailings fill, land and lakes, or clay settling area reclamation. The next step is revegetation, which is essential for soil stabilization. Soil erosion creates turbidity that can degrade water quality and cause excessive silt deposition into tributaries adjacent to the newly created landform. A proper revegetation plan "kick starts" the newly formed community by stabilizing soils, improving infiltration of rainfall, curbing flow velocities, and creating habitat value for wildlife. This section will examine the types of vegetation, establishment of "vegetative communities," and the practices and considerations that are associated with revegetating disturbed phosphate lands.

REVEGETATION PLAN

Both the mine operators reclaiming lands under the "mandatory reclamation program" and the landowner under the "nonmandatory reclamation program" (see page 24) are required to submit a revegetation plan. The "revegetation" plan provides details on the species, vegetative densities, diversity, and locations of vegetation to be planted as needed to demonstrate compliance with the "reclamation performance standards." During the preparation and design of the revegetation plan, many elements are considered including post-reclamation soils and site hydrology.

A major consideration in the development of a revegetation plan is regional benefits. Regional benefits consider water quality, water quantity, wildlife values, and land use function as related to compatibility with regional land use and/or land use plans. Thus, the revegetation plan designer must identify and define the functions of drainage features, land use, and vegetative communities of the adjacent lands. The basic concept is that since an operator must reclaim a minimum acreage of forest, wetlands, "greenbelts," etc., they should be located to provide maximum benefit and longevity.

The following illustration demonstrates the practice of optimizing the location of different types of vegetation on a reclaimed parcel. In this example, quantities of work effort and cost incurred by the mine operator are the same; however, in the second case a much greater benefit to the region was achieved.

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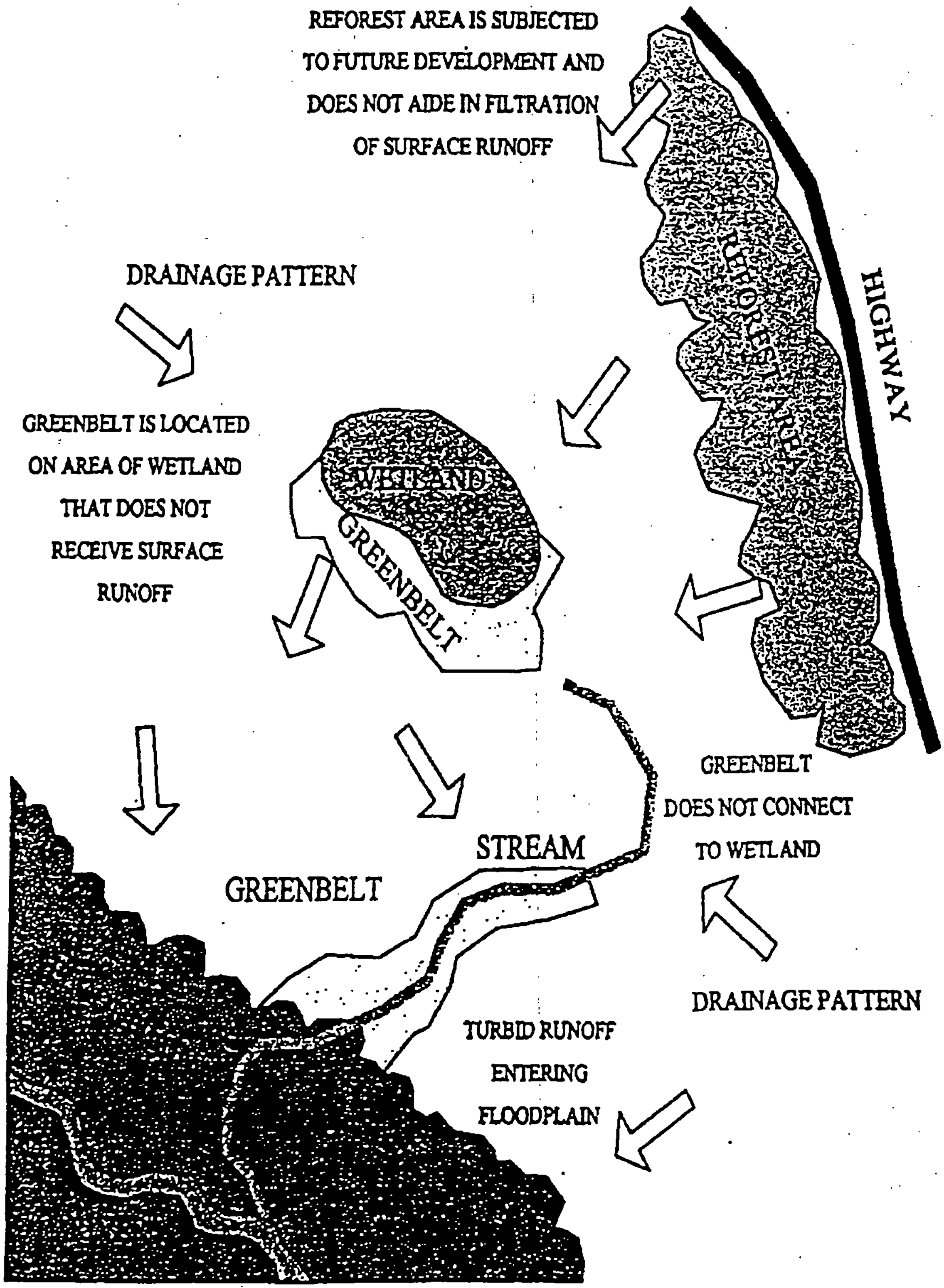
POORLY DESIGNED REVEGETATION PLAN



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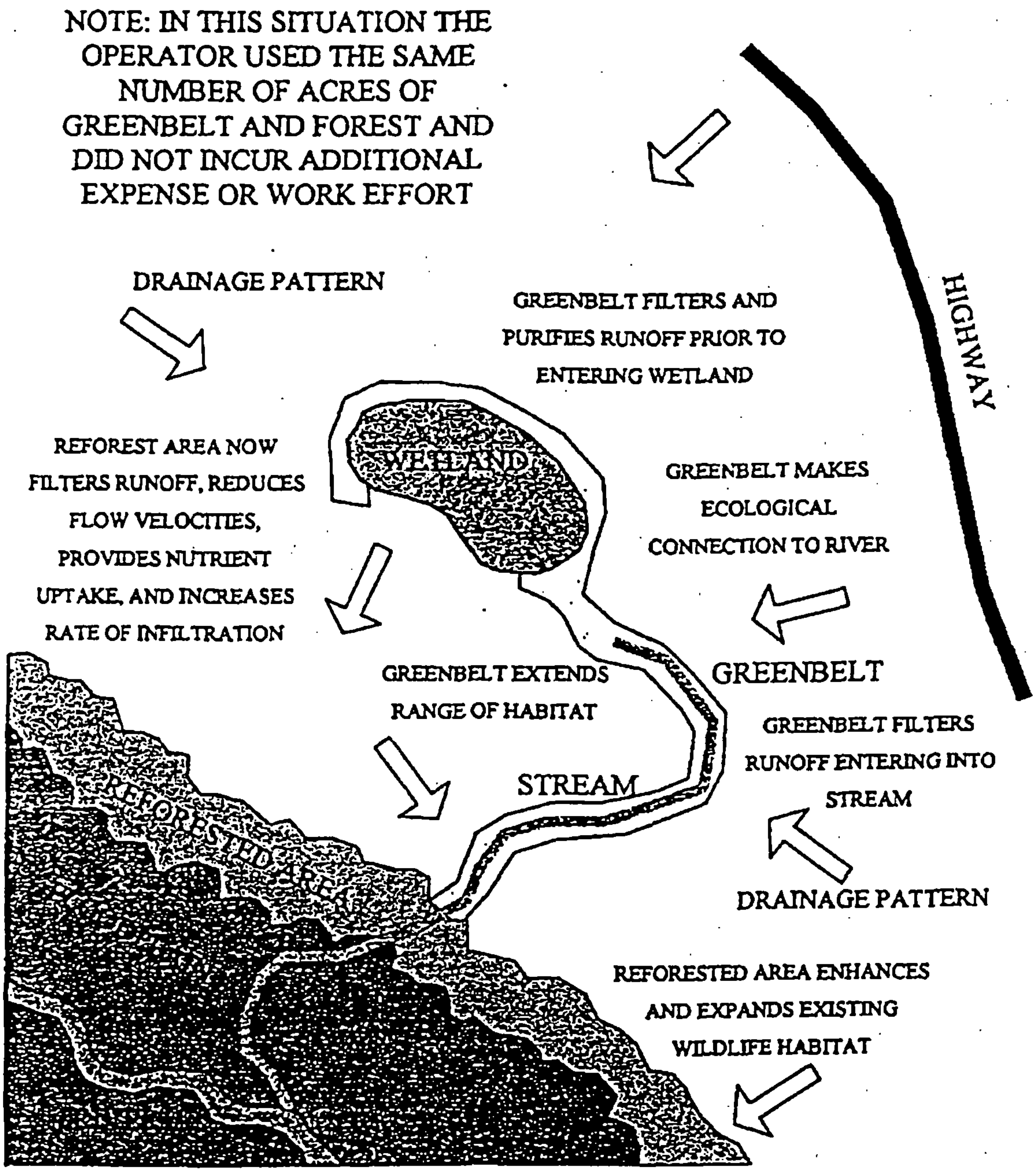
APPROPRIATELY DESIGNED REVEGETATION PLAN



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FLORIDA LAND USE, COVER AND FORMS CLASSIFICATION SYSTEM (FLUCFCS)

Since a large number of applicants submit reclamation plans to the Florida Department of Environmental Protection, Bureau of Mine Reclamation, it is important that land use/cover designations be the same. In addition, the level or the degree to which a classification is described is just as important. For example; if an applicant identifies that he will plant a forest, this does not indicate whether the forest will be a mixed forest of conifers and hardwoods or a monoculture of planted pines. In addition, there is no indication of whether the forest will be an upland or a wetland. Land use classifications are necessary to identify the land forms that existed prior to mining as well as the land forms proposed after mining and reclamation are complete. These land use/cover designations routinely serve the needs of other agencies regulating the phosphate industry and help provide consistency among the regulating entities. For proper evaluation, it is imperative that applicants and regulatory agencies utilize a standardized classification system.

A classification system was developed in 1976 by the Florida Department of Transportation to satisfy a wide variety of users and has been adopted by most of the state agencies. This classification system utilizes a numeric code that identifies the land use/cover and the level of its description. This system is referred to as the "Florida Land Use and Cover Classification System" (FLUCCS or FLUCCS-76). After publication of the original classification system, requests for specific identification of land cover became more demanding. An updated manual was published in September 1985 titled, "Florida Land Use, Cover and Forms Classification System " (FLUCFCS or "FLUCCS-85"), and is the currently accepted standard for most state agencies and local governments.

The "FLUCCS- 85" is arranged in hierarchical levels with each level containing land information of increasing specification. There are four levels in this system. Level I is the most general and Level IV has the greatest detail. These levels are generally described as follows:

Level I - This class of data is very general and is normally used for very large areas; e.g. statewide, or larger. Most mapping using this level is at scales ranging from 1:1,000,000 to 1:500,000 (one inch equals 16 miles to one inch equals 8 miles, respectively). Examples of this level of classification would be Urban, Agricultural, Upland Forest, etc.

Level II - This class of data further defines the classes of Level I. Mapping for this level is generally at a scale of about 1:100,000 (one inch equals approximately 8,000 feet). Examples of this level of classification would be Urban-Residential, Agricultural-Cropland, Upland Forest-Tree Plantations, etc.

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Level III - This level increases the classification detail above that of level II. Mapping for this level is generally at a scale of about 1:24,000 (one inch equals 2,000 feet). Examples of this level of classification would be Urban-Residential-Low Density, Agricultural-Cropland-Row Crops, Upland Forest-Tree Plantations-Coniferous Plantations, etc.

Level IV - This level provides the greatest classification detail. Mapping for this level is generally at a scale of about 1:6,000 (one inch equals 500 feet). Examples of this level of classification would be; Urban-Residential-Low Density-Mobil Home Units, Agricultural-Cropland-Row Crops-Tomatoes, Upland Forest-Tree Plantations-Coniferous Plantations-Sand Pine Plantations, etc.

Applications submitted for the purposes of reclamation classify land use to Level II. However, Level III is often used for detailed permit and mitigation requirements.

RECLAIMED VEGETATIVE COMMUNITY TYPES

The state reclamation laws require certain minimum standards to be met on lands from which phosphate has been severed. Although the mandatory and nonmandatory reclamation programs differ slightly in their reclamation standards, the legislature recognized that certain components were equally important to both programs.

The operator's revegetation plan should be designed to achieve permanent vegetation, minimize soil erosion, recognize the requirements for appropriate habitat for fish and wildlife, and improve aesthetics. The reclamation rules provide standards that address these concerns. For instance, the operator must achieve ground cover over 80% of the reclaimed upland areas with no bare areas exceeding one-quarter (1/4) acre. A minimum of 10% of the upland area must be established as upland forest where practical and consistent with the proposed land uses. Herbaceous wetlands are required to achieve a ground cover of at least 50% at the end of one year after planting and must be protected from adverse land uses for three years after planting. Forested wetlands must achieve a stand density of 200 trees/acre and be protected from adverse land uses for five years or until the trees are ten feet tall. All plant species utilized in revegetation activities must be indigenous species except for agricultural crops, grasses, and temporary ground cover.

In the reclamation of disturbed phosphate lands, there are four general types of vegetative communities; xeric, mesic, hydric, and aquatic. For these vegetative communities to be maintained, they have to be supported by a landform possessing the proper elements. A brief description of these communities, along with a description of their associated landforms, is as follows:

Xeric - An arid, dry to low moisture condition, in which only certain species of plants exist. The soils of these communities are generally deep-running, well-drained,

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marine deposited sands that are very low in silt, clay, and organics. This landform supports tree species such as longleaf pine, turkey oak, bluejack oak, sand live oak, etc. The tree species occurring on these lands are slow growing and typically have an open canopy. Some of the xeric communities found in the phosphate district include sand pine scrub, sand scrub, and xeric oak. This community type is fragile and has been significantly reduced in acres as a result of disturbance. Xeric areas can support many flora and fauna species that are on the endangered and threatened species and species of special concern lists.

Mesic - Characterized by dry to moist sand with varying amounts of clay, silt, or organic material. This community type supports a wide variety of both tree and shrub species. The climax communities within this type are generally conifers, hardwoods, or a highly diverse mix of conifers and hardwoods, often having a relatively closed canopy.

Hydric - These landforms generally possess flat slopes and are comprised of poorly drained sands, marl, or limestone substrates. The surface of these landforms generally contains a relatively thick layer of decomposing organic matter. The organic matter and the soils are normally saturated and are periodically inundated throughout the year. This landform supports tree species such as cypress, red maple, swamp bay, sweet gum, etc. Because of periodic "inundation," the understory density of forested areas is often sparse. The understory that does exist consists of species such as ferns, peppervine, yellow jessamine, Virginia creeper, etc. Nonforested hydric communities are dominated by herbaceous plants including common reed, panicum, cutgrass, southern water grass, Spanish needle, redroot, bulrush, pickerelweed, arrowhead, etc.

Aquatic - A landform that supports a body of water that stays inundated for the majority of the year. For the purposes of "aquatic communities" as related to reclamation, these systems are dominantly lakes and some wetlands having deep water zones. Shallow zones of these water bodies contain emergent, floating, and submergent species. Floating-leaved or submerged aquatic species include banana-lily, American lotus, spatterdock, fragrant water lily, coon tail, watermilfoil, bladderwort, fanwort, pondweed, etc.

It is important to understand that the community types of Florida are much more extensive than the general classifications mentioned above. In fact, the Soil Conservation Service, USDA (1985), has identified twenty-six (26) ecological communities in Florida. The communities mentioned in this document include only those that are utilized for the purposes of reclaiming mined lands. It is important to note that the descriptions of community types as discussed herein are similar but may differ from other descriptions used for other purposes.

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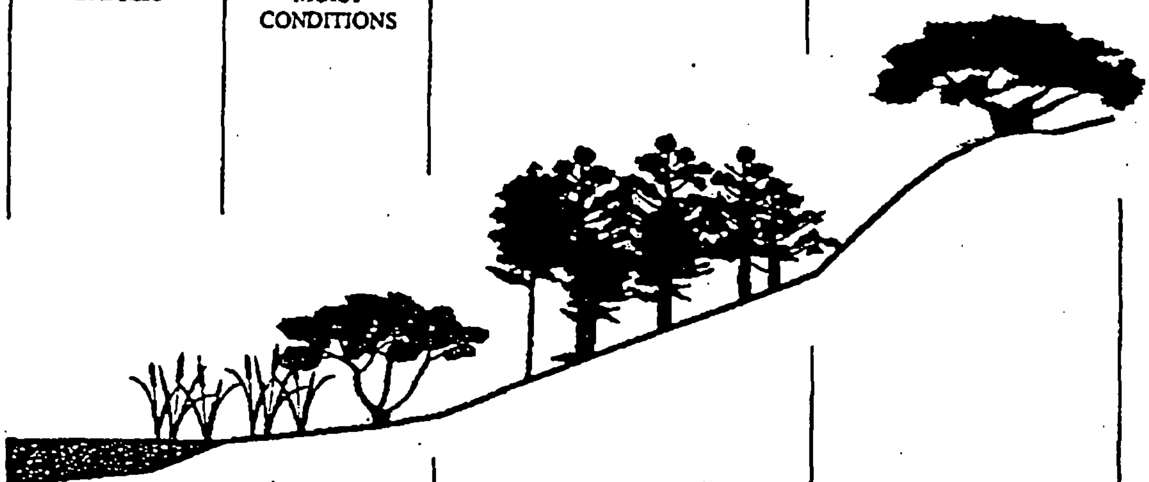
VEGETATIVE COMMUNITIES

AQUATIC	HYDRIC	MESIC	XERIC
CONTAINS EMERGENT, SUBMERGENT, AND FLOATING VEGETATIVE SPECIES	HERBACEOUS, SHRUB, AND TREE SPECIES THAT ARE ADAPTED TO MOIST CONDITIONS	THE MOST DIVERSE OF THE COMMUNITY TYPES AND SUPPORTS A MIXED FOREST WITH A CLOSED CANOPY AND A DENSE UNDERSTORY	SPECIES THAT ARE ADAPTED TO ARID OR DRY CONDITIONS, HAVE AN OPEN CANOPY WITH A SPARCE UNDERSTORY



SOILS THAT ARE INUNDATED ALL OR MOST OF THE YEAR	SOILS THAT REMAIN MOIST AND ARE SUBJECT TO PERIODIC INUNDATION	DRY TO MOIST SANDS THAT CONTAIN VARYING AMOUNTS OF CLAYS, SILTS, AND ORGANIC MATERIALS	RELATIVELY STERILE SOILS THAT ARE GENERALLY MARINE DEPOSITED DEEP RUNNING SANDS THAT HAVE A LOW POTENTIAL FOR HOLDING MOISTURE

SOIL DESCRIPTIONS

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NATURE OF RECLAMATION SOILS

Mining operations conducted to recover phosphate ore disturb the natural soils that have developed over millions of years. In the mined areas, the soil column may be inverted such that soil materials that were once 20 to 50 feet beneath the surface may be at or near the surface. The many soil horizons within the overburden also become mixed changing the overall soil structure. However, this is not all bad. The majority of the natural soils of central Florida are at best moderate as a suitable growing medium due to their high composition of sands and loams. Many natural soils are considered "droughty" due to their inability to retain moisture. As discussed in the *Geologic Formation of Phosphate* section of this document, the clay content of the overburden increases with depth, i.e., the closer it is to the matrix. Thus, the higher clay content of the newly created reclaimed soils allows more moisture retention via infiltration making more moisture available for plant growth within the plant root zone. In addition, soils with higher clay content have a higher cation exchange rate, making them less susceptible to becoming acidic.

The creation of a suitable growing medium in sand tailings areas presents a challenge to the industry. The sand tailings generally have a low moisture holding capacity and are very low in nutrients. On their own, they have limited characteristics for supporting vegetation until topsoil develops. As discussed in the section, *Sand Tailings Fill and Reclamation,* sand tailings disposal areas are capped with overburden of an adequate thickness to provide the growing medium required to support the intended vegetation. This cap thickness varies depending upon material availability and the types of vegetation to be planted. For some sand tailings disposal areas, sand tailings are not capped with overburden; rather, selected top soils are used to create xeric habitats, while other areas may be capped with muck or other organic soils to create wetlands.

The phosphatic clays contained in clay settling areas are an ideal growing medium for most vegetative species. However, these soils lack the permeability of other type soils which can lead to poor drainage conditions. In some cases, a relatively thin cap of overburden or sand tailings may be placed over the clay surface and disked into the clay to aid in the soil's tilth and permeability. In most cases however, all that is required for these soils is to provide adequate surface drainage.

A special case in the creation of reclamation soils is in the establishment of wetland and water body plant species. Emergent and submergent species of vegetation require the establishment of a hydroperiod. A essential key to establishing these types of species is the presence of mycorrhiza. Mycorrhiza is a fungus that has a mutually beneficial association with the roots of many plant species. The fungi interact with the root tissues in a way that increases the plant's ability to extract nutrients from the soil. Many of the emergent and submergent plant species cannot be grown successfully unless the fungi are present. When naturally occurring wetlands and water bodies are to be disturbed by mining operations, the muck or muck soils can be removed and stockpiled. These basically organic materials which contain mycorrhiza are later used to inoculate the newly created soils of reclaimed wetlands and water bodies. This is accomplished by spreading the muck material over the surface to be inundated. Another way to obtain mycorrhiza is to remove wetland vegetation from naturally occurring wetlands ahead of mining and transplanting the plant materials into the reclaimed wetland area. The mycorrhiza contained on plant roots and soil will be introduced to the reclaimed wetland through this method.

In moving earthen materials to obtain the appropriate contours, heavy equipment may traverse the same area numerous times. This may result in over-compaction of the surface soils. These compacted soils can be less conducive for plant growth and root penetration. In addition, the heavy equipment may also leave an irregular surface. The common practice of the mine operators is to disk these lands with agricultural tractors to obtain a better tilth of the soil and to remove most of the surface imperfections. Once the soils have been disked, a harrow is used to provide the final smoothing and obtain the necessary soil tilth. In many instances, the surface is seeded with grasses between the time the soils are disked and harrowed. This covers the seeds with approximately ½ inch of soil to assure a better germination rate.

BEST MANAGEMENT PRACTICES

Once the soil surface has been prepared, a certain amount of time can be expected before the lands are planted, seeds germinate, and adequate vegetative density is obtained. During this time, as in all agriculture practices, the soils are left exposed to the elements and are subjected to movement, during which time erosion, sedimentation, and degradation of water quality can result. To reduce these occurrences, the industry applies best management practices (BMP's) to these lands. There are numerous types of BMP's and all of these practices will not be covered within this document. Rather, only a few of those that are commonly applied are discussed.

Erosion prone areas are mulched with biodegradable materials to reduce soil movement. These mulch materials also assist in retaining the moisture content of the soils. Areas that are subjected to severe erosion, such as swales and channels, are sodded. Silt fences, hay bales, or a combination of these are placed along the edges of floodplains, water conveyance systems, water bodies, wetlands, property boundaries, and so on. Rip rap is sometimes used in channels of swales and ditches that will have excessive energy flows. Some areas are protected by designed and constructed stormwater ditch and berm systems, which are placed between mining and protected areas and are left in place until the area has been mined, reclaimed and completely vegetated. Once sufficient vegetation has been established, and the area is "released", the ditch and berm system can be removed and the area reconnected to the natural drainage system.

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It should be noted that although state reclamation laws do not require the use of these practices, they do regulate the occurrence of erosion, sedimentation, and affected water quality and quantity. Thus, it is left to the mine operators to apply these practices to meet state reclamation performance standards. Individuals interested in more information regarding the accepted types and proper construction of these practices may inquire to the Institute of Food and Agricultural Sciences (IFAS), University of Florida; Natural Resources and Conservation Services, US Department of Agriculture; US Forest Service; Division of Forestry, Florida Department of Agriculture; and the Florida Department of Transportation.

RECLAMATION LAND COVERS

General:

Unlike most environmental impacts that are regulated by the State, phosphate mining is a temporary use of the surficial landscape to extract the underlying mineral resource. Even so, the phosphate mining companies have an interest in the post-reclamation landform, accomplished through economical reclamation that meets all permit and regulatory requirements. Good reclamation design will replace the pre-mining landforms with post reclamation landforms that supply the same or greater benefits to all of the users of the land. The regulations provide minimum standards to accomplish this goal, including specific performance standards for numbers of trees, species diversity, and ground stability. Reclamation of critical wildlife habitat or wetland landforms is typically controlled by specific permits issued by local, state, and federal agencies. These permits require acre for acre or greater replacement of certain desirable habitats and include specific conditions for species, cover, hydrology, soils, and monitoring.

The following sections describe the methods used to create various reclamation land types. These sections are general, and do not provide specific details associated with particular permit programs or departments within government.

Pasture and Rangeland:

Reclaimed areas are usually revegetated with a mixture of annual and perennial grasses after completion of final grading to provide a stable ground cover that will resist erosion and sedimentation/siltation damage. The grass seed mixture and initial fertilizer application rate will vary, depending on soil fertility testing, anticipated hydrology, and the proposed land form. Generally, the initial grassing includes two or three annual species to provide a quick cover and help to establish an organic component in the fresh substrate. Typical species are rye grasses in the winter and millet in the summer. Additional species which may be planted to promote nitrogen fixing and enhance organic soil development include legumes and species such as

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Aeschynomene, Indigo, and Alyceclover. These may be inoculated with nitrogen fixing bacteria cultures.

Improved pasture areas are generally seeded with a mixture of bahia and bermuda grasses. These are essential to minimize erosion and turbid run-off. Landforms which are being constructed to replace existing rangeland may be seeded with additional native and non-native species, if available. Currently, native seeds are not commercially available in sufficient amounts to meet the reclamation needs. Both the phosphate industry and the Florida Institute of Phosphate Research are working to develop additional sources. Species which are currently available for rangeland development include chalky bluestem, lopsided indian grass, lovegrass, stiffleaf cloris, beggarweed, and switchgrass. However, quantities are very limited. To fully develop pasture and rangeland land forms, some additional supplemental planting with nursery grown stock or harvested plants is usually undertaken during the second growing season.

Upland Forest:

Upland Forest areas are usually planted with trees during the first planting season following establishment of the initial ground cover. This initial groundcover is generally an annual and perennial mix of grasses. Grasses may include native species such as wire grass, broomsedge, and legumes, as well as bahia and bermuda. If necessary, areas to be planted will be mowed at the beginning of the planting season. Trees are usually planted to achieve a minimum density of 200 trees per acre at the end of a one year establishment period.

The tree species planted will depend on the type of forest cover being established, the hydrology of the landform, and the type of soil substrate. Typical mixed upland forest areas are planted with live oak, water oak, and slash pine. Additional hardwood and wildlife value species are planted within the upland forest at a density of about 10 to 20 trees per acre, including but not limited to; persimmon, wild cherry, pignut hickory, red cedar, chickasaw plum, dogwood, and sugarberry. Dry sandy areas are planted with scrub species such as turkey oak, sand pine, myrtle oak, blue jack oak, and Chapman's oak. Areas that may transition into a forested wetland or floodplain may be planted with loblolly bay, laurel oak, red cedar, and sabel palm. Areas that are reclaimed to replace or provide additional wildlife habitat may be planted with shrub and brush species at the same time the trees are planted. The number and species to be planted are specified by permit conditions. Commercially available species include saw palmetto, gallberry, wax myrtle, and fetterbush.

When properly located, upland forest areas provide excellent filtration of surface water runoff, remove excess nutrients, and enhance and expand adjacent wildlife habitats.

Forested Wetland:

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Forested wetland reclamation requires coordination of hydrology, existing landscape features, and earthmoving design to create a site that allows the planted wetland vegetation to grow and flourish. The ephemeral nature of existing wetlands is apparent in our geological history. To create forested wetlands requires a balance of hydrology, organic soils, and wetland plants to provide similar conditions as found in nature.

Where available, revegetation of a forested wetland typically starts with the spreading of muck and plant material from a donor site or stockpile. Water levels are monitored and temporarily adjusted during muck spreading and establishment to promote recruitment of wetland plant and shrub species. Specific permit conditions dictate the number and species of trees to be planted. Typically, trees are planted at a density of 600 trees per acre. Native species are selected and planted in zones according to their hydrologic requirements. Transitional species, such as slash pine and water oak are planted at the outer edge. Those species that require standing water or that are tolerant to long periods of inundation are planted toward the center or deepest areas. As shade develops within the wetland, additional shrub and brush species may be planted within the wetland.

Monitoring and maintenance of forested wetlands occur throughout the establishment process. Moisture conditions may be adjusted in the establishment phase by pumping water into or out of a site, and for post reclamation sustenance by adjusting the inflow and outflow connections. Nuisance and exotic species are controlled by herbicides and mechanical removal. Measurements of tree mortality, growth, and diversity are made at periodic intervals to gauge success.

Herbaceous Wetland:

The same considerations for forested wetland reclamation apply to herbaceous wetland reclamation. The hydrology, soils, and plant species need to be coordinated to provide conditions that allow this type of community to grow and flourish. Herbaceous wetlands support a wide variety of wading and migratory birds, mammals, reptiles, amphibians, and invertebrates.

Where available, the revegetation of a herbaceous wetland typically starts with the spreading of muck and plant material from a donor site or stockpile. As with forested wetlands, the more water tolerant species are planted toward the center, with less tolerant species planted toward the outer perimeter. Water levels are monitored and temporarily adjusted during muck spreading and vegetation establishment to promote recruitment of wetland plant and shrub species. Permit conditions usually require a minimum percent cover by the second or third growing season after the spreading of muck. Supplemental planting is required if this minimum cover is not reached.

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Monitoring and maintenance of herbaceous wetlands occur throughout the establishment process. Moisture conditions may be adjusted by pumping water into or out of a site, and by adjusting the inflow and outflow connections. Nuisance and exotic species are controlled by herbicides and mechanical removal. Measurements of growth and diversity are made at periodic intervals to gauge creation success.

Waterbody:

As areas are mined, the pits left from the mining operation are filled with reclamation materials such as overburden or sand tailings. Lakes are planned based on material balances and hydrology. See also, the section on *Land and Lakes Reclamation.* Governmental regulations provide minimum standards for lake design and construction. These standards were established to ensure that reclaimed lakes provide beneficial uses within the post reclamation landscape.

Lake shape, elevation, depth, outfall connections, and upland contributing area are created by balancing the hydrology study with the earthmoving design. The hydrology study provides an estimate of the elevations through which the lake will fluctuate between wet and dry seasons. This fluctuation is often called a "zone of fluctuation," or "littoral zone" and regulatory agencies provide that a lake will have a minimum surface area within this zone to provide habitat and water quality enhancement in the post reclamation environment.

The zone of fluctuation around a waterbody can be reclaimed to provide the same functions for wildlife and water quality as a reclaimed forested or herbaceous wetland. Revegetation of a littoral zone can occur either through the spreading of muck and recruitment, or through the planting of desired species directly into the reclaimed substrate. Water levels are monitored and artificially adjusted during establishment to promote recruitment of wetland plant and shrub species. Permit conditions usually require a minimum percent cover by the second or third growing season after the completion of the water body construction. If this minimum cover is not reached supplemental planting is required to achieve the required cover.

Monitoring and maintenance of littoral zones occur throughout the establishment process. Moisture conditions may be adjusted in the establishment phase by pumping water into or out of a lake, and for post reclamation sustenance by adjusting the inflow and outflow connections. Nuisance and exotic species are controlled by herbicides and mechanical removal. Measurements of growth and diversity are made at periodic intervals to gauge creation success.

Greenbelt:

State regulations provide two methods for natural treatment of runoff that enters a reclaimed water body. The first method requires construction of detention areas that impound the initial runoff volume and allow natural biological and physical processes to improve water quality. The second method is creation of a "greenbelt." Greenbelts are strips of forested land that often surround water bodies. The shrub, brush and tree species within a greenbelt impede overland water flow, reducing flow velocities and increasing detention time. This allows natural biological and physical processes to improve the water quality. The vegetation provides uptake of nutrients and creates a buffer of organic matter that stabilizes water conditions.

Greenbelts are vegetated in much the same way as forested upland areas. The graded substrate is grassed to stabilize the surface and to prevent erosion and turbidity/siltation damage. Trees are then planted during the first planting season following establishment of the initial ground cover. Trees are usually planted to achieve a minimum density of 200 trees per acre at the end of a one year establishment period. The tree species planted depend on the type of forest cover being established, the hydrology of the landform, and the type of soil substrate. Greenbelts are typically planted with live oak, water oak, and slash pine in the upper slopes. Transitional species such as laurel oak, longleaf pine, and red cedar are planted on the lower slopes and around outfalls and inflow areas.

To enhance the wildlife value of the greenbelt areas additional hardwood and wildlife value species may be planted at a density of about 10 to 20 trees per acre. Such species may include, but are not limited to; persimmon, wild cherry, pignut hickory, red cedar, chickasaw plum, dogwood, and sugarberry. Areas which are reclaimed to replace wildlife habitat or to provide corridors for wildlife use may also be planted with shrub and brush species at the same time as trees are planted. Tree survival density and representative species to be planted are specified by permit conditions. Commercially available species include saw palmetto, gallberry, wax myrtle, and fetterbush.

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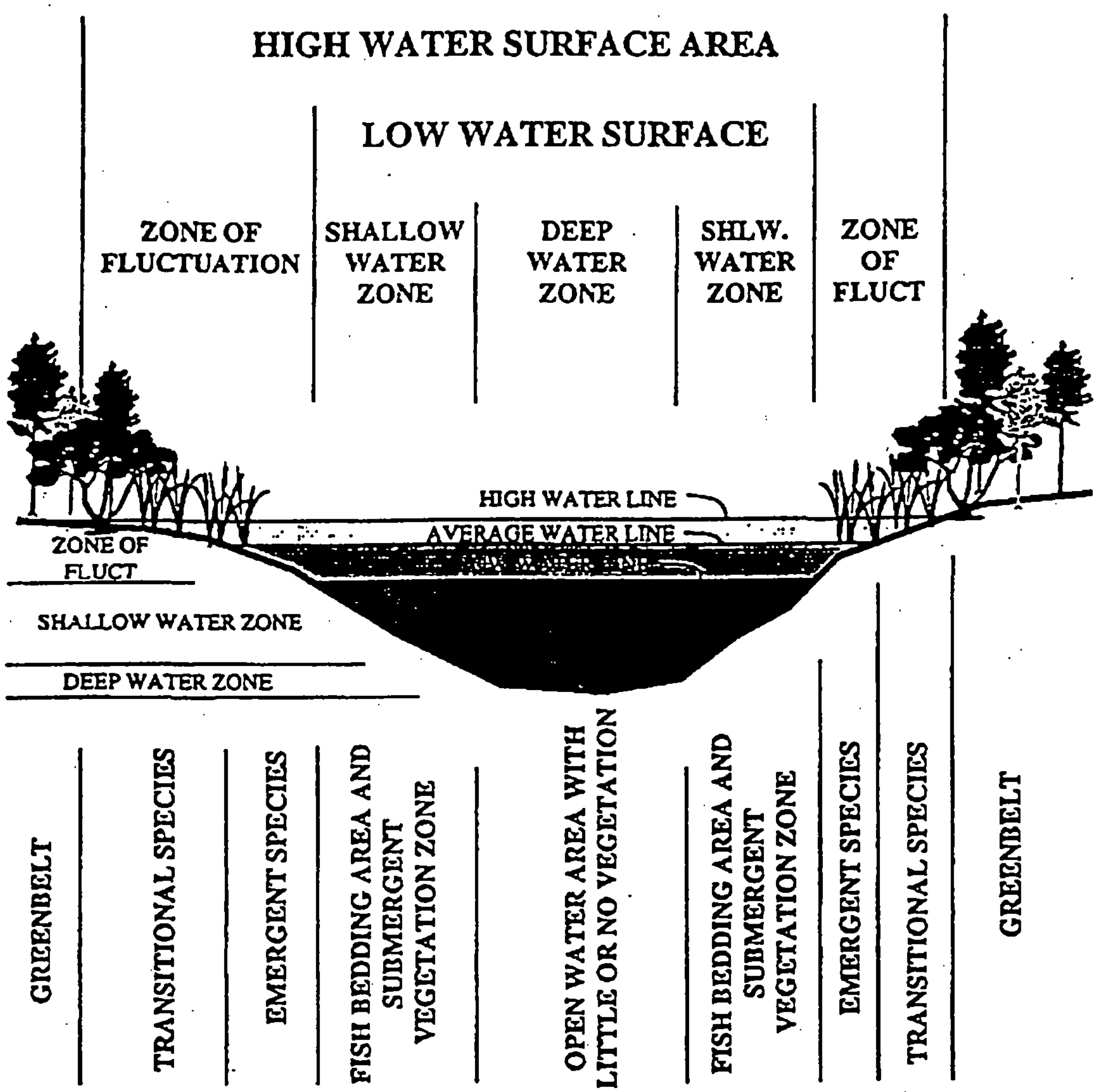

VEGETATIVE COMMUNITIES

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INTEGRATED HABITAT NETWORK

Since the development of mandatory land reclamation conceptual plans in the early 1980's, the focus has been on ecosystems. Mine wide conceptual reclamation plans and Developments of Regional Impact (DRI's) were the first attempt at viewing reclamation from a broader perspective than individual reclamation programs. As the practice of reclamation evolved and knowledge was gleaned from past experiences, it became obvious to the Bureau that the realistic and effective planning of reclamation must extend beyond each mine's conceptual plan. Thus, the "Integrated Habitat Network/Coordinated Development Area" (IHN/CDA) concept was conceived.

Simply stated, the IHN/CDA is a plan that addresses regional reclamation issues. To understand the need for a regional plan, an examination of the elements of that plan must be considered. Mine-wide conceptual plans, although an excellent approach in their day, did not always consider the reclamation or land uses of adjacent areas. The conceptual plans consider reclamation enhancements to natural features adjacent to or within the mine boundary. However, they do not apply a broad ecosystem approach. Reclaimed phosphate lands in the rapidly developing Central Florida area are prime areas to receive residential and commercial growth. Thus, considerations for locating reclaimed areas to provide the desired water quality and quantity, and to create quality wildlife habitats, need to include those reclaimed land uses that will maximize the longevity of the reclamation efforts. Unfortunately, fragmentation of ecosystems has occurred from past agricultural operations, as well as from past and current development.

From this regional concept, a district-wide conceptual reclamation plan was generated for the entire southern phosphate mining district. This district plan was then used to form a larger regional plan. The goals of the district-wide conceptual plan are to encourage reestablishment of drainage and hydrologic function, organize land uses to maximize their longevity and water clarification capacities, and improve quality wildlife habitat and corridors. These lands are separated into two categories; (1) those to be included in the Integrated Habitat Network, and (2) those to be included in the Coordinated Development Area.

The Integrated Habitat Network lands are designed to maximize habitat replacement, protection, and connection; to provide a buffer for surface runoff entering drainage features; and to be undisturbed by development. The lands in the Coordinated Development Area are designed to be subject to development and to provide areas for more intensive human use, while still providing for protection of water resources.

Within the Central Florida phosphate district, there are five major river systems. Because of their environmental sensitivity, these rivers and their major tributaries received only minimal disturbance from mining operations. These natural systems of

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rivers and tributaries provide the basic framework of the IHN. Building on this framework, one goal of the IHN is to enhance and expand this natural drainage structure through reclamation. Enhancement of these systems includes connecting fragmented portions and supporting wildlife by creating habitats on adjacent lands. These efforts to expand the IHN will connect that framework to other natural features within the region. In concept, expanding this natural drainage system one mile to make a connection to an existing system, could extend the system an additional 50 miles. Done several times, this would provide obvious benefits. To accomplish these enhancements and expansions, the Bureau has worked closely with the industry to develop appropriate and economical habitat design, construction, and revegetation methodologies.

The location of travel corridors along natural and man-made drainage features has benefits in addition to those for wildlife. These "greenway" corridors also help in water quality protection and water quantity maintenance by establishing a forested buffer zone. A forest floor has layers of leaves, branches, and other organic matter. Woodland soils and decomposing organic materials act as a natural sponge to intercept, store, and slowly release runoff water into streams and underground aquifers. In fact, woodlands absorb 15 to 40 times as much water as pastures and tilled cropland. As runoff water slows, chemical contaminants are trapped and transformed by microbes into nontoxic forms. At the same time, tree roots take up nitrogen and phosphorus.

The following are some of the benefits that are being achieved through implementation of the IHN:

Trapping, filtering, and transforming nonpoint source pollutants from groundwater and surface runoff.
Stabilizing streambanks with the framework of roots.
Converting nitrate into nitrogen gas.
Increasing oxygen levels in streams by shading water to keep it cool.
Slowing water velocity and erosion.
Supplying food and habitat for fish and aquatic creatures, birds, and other animals.
Providing pathways and corridors for wildlife.
Improving the biological diversity of the region.

The implementation of the IHN presents many challenges. Lands reclaimed for economic use generally have a higher tax base than lands reclaimed for environmental purposes. Although the re-establishment of a natural environment is important to local governments, these local governments must also consider their future economic well-being. Phosphate is a finite resource that will eventually be depleted. Although the phosphate industry currently provides numerous jobs to the local communities and contributes greatly to the tax revenue, and in turn, government services, a balance is required to weigh the future economy with that of the environment.

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For the IHN/CDA to be effective for the long term, it is essential that habitat quality, water resources, and economic uses be properly managed and protected. The Bureau is presently working with other state, local, and regional governments as well as the mining industry to develop a management and protection plan for these lands. This management and protection plan will account for the uses of the IHN/CDA lands and how those uses will affect the adjacent lands and waters. Recognizing that management and protection activities of the IHN lands differ from those of the CDA, separate activities for each will be developed.

The basic principles of management and protection for the IHN lands are to ensure the establishment of the appropriate biodiversity, enhance existing biodiversities, and provide a self-maintaining quality habitat. The management and protection principles of the CDA lands are the development of land uses that are consistent and compatible with the lands of the adjacent IHN. Once the management and protection plan has been completed and agreed to by all entities involved, that plan will be incorporated into and made part of the regional program.

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ESTABLISHMENT OF APPLIED RECLAMATION PRACTICES

INTRODUCTION

Following the earthmoving and revegetation stages, land reclamation sites are subject to the same varying weather conditions as natural sites such as drought, rainfall, wind, extreme temperatures, and other forces of nature. Fire, disease, animal, and human impacts can also result in the loss of reclamation efforts. To assure that the reclamation will maintain itself after the reclamation efforts have been completed, state reclamation regulations make provisions for the maintenance of those efforts.

The regulations require that standards be met for a period of time after the physical efforts of reclamation are completed. This period of time is commonly referred to as the establishment period. For upland reclamation, this period is usually one year after planting. For lakes and wetlands, this period is usually five years after planting. Non-mandatory lands, where the owner has received refunds from the State, must also remain in the same land use form as approved for at least five years. To assure that the reclamation efforts will meet the reclamation standards at the end of the establishment period, state inspectors and mining company representatives monitor the maturing reclamation. If those inspections indicate that efforts are currently insufficient or are likely to be insufficient by the end of the establishment period, remedial actions are taken by the operators.

RECLAMATION MAINTENANCE

During the establishment period, it may be necessary to repair or replace vegetation or correct erosion problems. Mowing and/or fertilizing grasslands may be necessary to improve vegetation density and reduce the potential for invasive species to dominate the site.

Fertilizer is applied based on chemical analysis of the soil and/or foliar analysis of leaf material. To insure vegetation establishment, a second fertilizer application may be required.

To insure survival of planted vegetation, it may be necessary to irrigate during periods of drought or pump water out of areas during periods of excess rainfall. This manipulation of water during the establishment period helps to insure survival to meet standards. Firebreaks are planned within and around the reclaimed areas to assist in preventing large losses as a result of wildfire. Special attention is given along public highway rights-of-way due to greater potential for fire being started by passing motorists. Maintenance of firebreaks is important as the ground cover matures.

Taking the above mentioned precautions helps to reduce the potential for losses in a reclaimed site just as for natural sites, but no plan is 100% effective. Such things as

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disease, pests, unexpected human or animal damage and certain natural disasters cannot always be predicted. Thus, the operators usually plant more vegetation or trees than are required to help insure adequate numbers at the time of release following the establishment period. However, in some cases, vegetation may have to be replanted if sufficient numbers do not exist at the time of release and the project must go through another establishment period.

Some operators graze cattle on reclaimed lands. Cattle must be managed to prevent destruction of vegetation or erosion prior to release. Fencing or restriction of cattle from specific areas should be considered in the management plan. Cattle in newly planted, forested areas will damage planted trees.

REPLANTING AND PLANT SURVIVAL

As previously stated, state inspectors and company representatives monitor the survival rate of the vegetation and determine throughout the establishment period if the reclamation efforts will meet the standards. If it appears the vegetation will not meet the standards, the operators will supplement the vegetation with additional plantings. The initial planting and any supplemental plantings are normally planted to exceed the minimum standards so that release of the project is not delayed. At the conclusion of the establishment period, state inspectors will determine if the required average density/coverage of vegetation and composition of species have been met.

EROSION

Reclaimed soils, until adequately revegetated, are subject to the erosional processes of nature. Weather patterns in Florida normally consist of frequent thunderstorms and long periods of heavy, seasonal rains. When these rains occur on unvegetated soils, soil particles move. This movement of soil particles is one form of erosion. Wind may also have an erosional effect on unvegetated soils, but is less of a problem in Florida than rainfall. There are several types of erosion and these types are segregated by their degree of severity. These types and a brief description of each are as follows:

Gully Erosion – This type of erosion is caused from the forces of running water and is the most severe and damaging of the erosion types. Deep channels are formed that further exaggerate the condition. The channels concentrate the flows of water and, if not corrected, can quickly become deeper and wider. On reclaimed phosphate sites, rarely are these channels greater than two feet deep. Large quantities of soil material are moved in this type of erosion and are deposited as sediments in a concentrated area. Repair of this type of erosion requires heavy equipment and, in many cases, fill material is used to fill the void areas. The existence of this type of erosion indicates that high water volumes and velocities are occurring at that location. Thus, normal reclaimed vegetative covers are not adequate to prevent this occurrence. Operators

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The act of sedimentation and the suspension of particles have many detrimental effects on the environment. The suspended fine particles of clays, silts, and organic materials degrade water quality. This reduction in the quality of water can affect or significantly alter the overall ecology of an area. These finer particles have been known to kill fish by depleting available oxygen supplies in the water and clogging the fish's gills. The larger particles, generally sand size, can clog natural and artificial drainage features, causing flooding in some areas and depriving others of needed water. The act of sedimentation can kill plants by completely covering them with sediments and can even kill trees by smothering their root systems. These are only a few of the detrimental effects sedimentation and the transport of particles can have. The best way to stop *sedimentation is to stop it at its source, the point of erosion.*

EXOTIC, NUISANCE, AND INVASIVE SPECIES CONTROL

Water bodies within the State of Florida are generally rich in nutrients. This, combined with warm temperatures and clear skies, make plant growth prolific in Florida lakes. Reclaimed lakes may also provide a nutrient rich environment in which invasive aquatic plants become established. Many of these species, if left uncontrolled, will dominate an area and will create monocultures. State reclamation regulations recognize the importance of the control of these species and limit their occurrence on reclamation sites. Operators may employ physical, chemical, and/or biological remedies to control the growth of aquatic plants. Cultural practices such as the removal of aquatic plants before and after boat launching are also practical to prevent the spread of undesirable aquatic plants.

The occurrence and control of exotic, nuisance, and invasive species are involved and complex. The detail necessary to fully understand this situation will not be provided in this document. What is important is that reclamation practices are designed to eradicate or control these species. In addition, research into new and improved control methodologies is ongoing.

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generally use a combination of best management practices and sodding to correct the condition.

Rill Erosion – One of the most common types of erosion on phosphate lands is a result of running water. This type of erosion forms numerous small channels that are only a few inches deep. Large quantities of sediments can be generated from this type of erosion, but they are not as concentrated within an area as that of gully erosion. The repair of this type of erosion can normally be performed with conventional farm equipment. In some cases, this type of erosion removes the topsoil. Because the revegetation of these erosion prone areas is critical, the soil surface is dressed with a suitable growing medium. A heavy application of annual and perennial grasses and mulching is generally sufficient to correct these occurrences.

Sheet Erosion – This type of erosion removes a relatively thin and uniform layer of soil by flows of surface runoffs. This type is easy to repair and can be performed with the use of conventional farm equipment. In most cases, the soil surface is disked and harrowed and then heavily seeded with annual and perennial grasses.

Splash Erosion – This type of erosion is caused from the impact of raindrops on the soil surface that dislodge the soil particles. Identification of this type can be from field observation of rocks and pebbles sitting on a pedestal of soil. The rocks are not moved by the impact of the rain drops and protect the soil particles beneath them. The amount of soil loss can be estimated from the height of these pedestals. This type of erosion is less severe than other types and in most cases does not require repair.

Wind Erosion – This type occurs when the wind detaches and transports soil particles. Reclamation sites are large in size and prior to revegetation do not have barriers such as trees to reduce the energy of the wind. A major impact that wind erosion has on reclamation is that the wind driven soil particles can bruise and damage the growth of young vegetation. Wind erosion is a short term concern. Once annual grasses are established, this type of erosion ceases. Repair is generally not required.

SEDIMENTATION

If erosion occurs, then so does sedimentation. Sedimentation occurs when the energy of running water or wind reduces to the point that the suspended particles of soils fall out and are deposited. Unlike erosion that occurs in a defined location, the process of sedimentation can occur over vast areas. When the energies of running water and wind reduce, the larger suspended particles settle out first. The remaining lighter suspended particles may travel considerable distances before the energy levels reduce enough to allow for their deposition. Because of this, the act of sedimentation has a greater impact on the environment than that of erosion.